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Ontario Ministry of the Environmen
Detroit, St. Clair,
St. Mary's Rivers Project
Regional Characterization and
Waste Site Inventory
Volume I

INTERA

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Ontario Ministry of the Environment
Detroit, St. Clair, St. Mary's Rivers Project
Regional Characterization and Waste Site Inventory
Volume I

Prepared By

INTERA Technologies Ltd.

FINAL REPORT

March 1986

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1.0 INTRODUCTION

In November 1984, INTERA Technologies Ltd. (formerly GTC Geologic Testing Consultants Ltd.*), submitted a technical proposal to Ontario Ministry of the Environment, in response to a request for proposals, for professional services related to the Upper Great Lakes Connecting Channels Study. On December 7, 1984, GTC was informed that it had been successful in the competitive bid. A contract between the two parties was entered into on December 14, 1984. The aims of the work program, designed by the Ontario Ministry of Environment (MOE), were to develop a reference document which:

i) summarized the physiological conditions of the study areas;
ii) presented brief outlines on the operation of waste containment facilities based on a review of existing data.

The contractual terms of reference and objectives of the work program were to:

- Describe the geology, hydrogeology and physiology of the areas perceived by the MOE as most likely to contain waste sites that could negatively impact the water quality of the Detroit River, St. Clair, St. Mary's River and Lake St. Clair. The study areas were identified as that area west of longitude 82° for the Counties of Lambton, Essex and Kent as well as that area immediately surrounded by Algoma Steel and the Cherokee Landfill site in Algoma District. Potential impacts from sites located in the United States were not included in this study;

*Note: In April 1986, GTC Geologic Testing Consultants Ltd. adopted the name of its parent company, INTERA Technologies Ltd. In order to avoid confusion, the name GTC is retained in this report.

- Meet with Ontario Ministry of Environment officials in Sault Ste. Marie, Sarnia, Windsor, London and Toronto in order to directly access information pertaining to the various waste sites within the study area;

- Meet with a representative of Algoma Steel and the Lambton Industrial Society (L.I.S) in order to explain the nature and objectives of the study;

- Establish the active or inactive status of the waste sites in the study areas.

The study areas are shown in Figures 1.1 and 1.2.

This report addresses primarily the Sarnia-Windsor area and places less emphasis on the Algoma District. The emphasis on the Sarnia-Windsor area is a result of the large number of waste disposal sites (approximately 100 active or inactive sites) in the Sarnia-Windsor area versus the relatively few sites in the Algoma District. As well, the volume of information available for the two areas is heavily weighted toward the more populated area of southwestern Ontario.

To achieve the goals of this study, extensive data have been compiled and reviewed. The material includes information from Ontario Ministry of Environment regional and district offices, Ministry of Natural Resources, Environment Canada, Geological Survey of Canada and other government organizations as well as journal articles, consultants reports and field site visits. Every attempt was made to obtain as much regional and site specific information as the project scope, budget and time would allow.

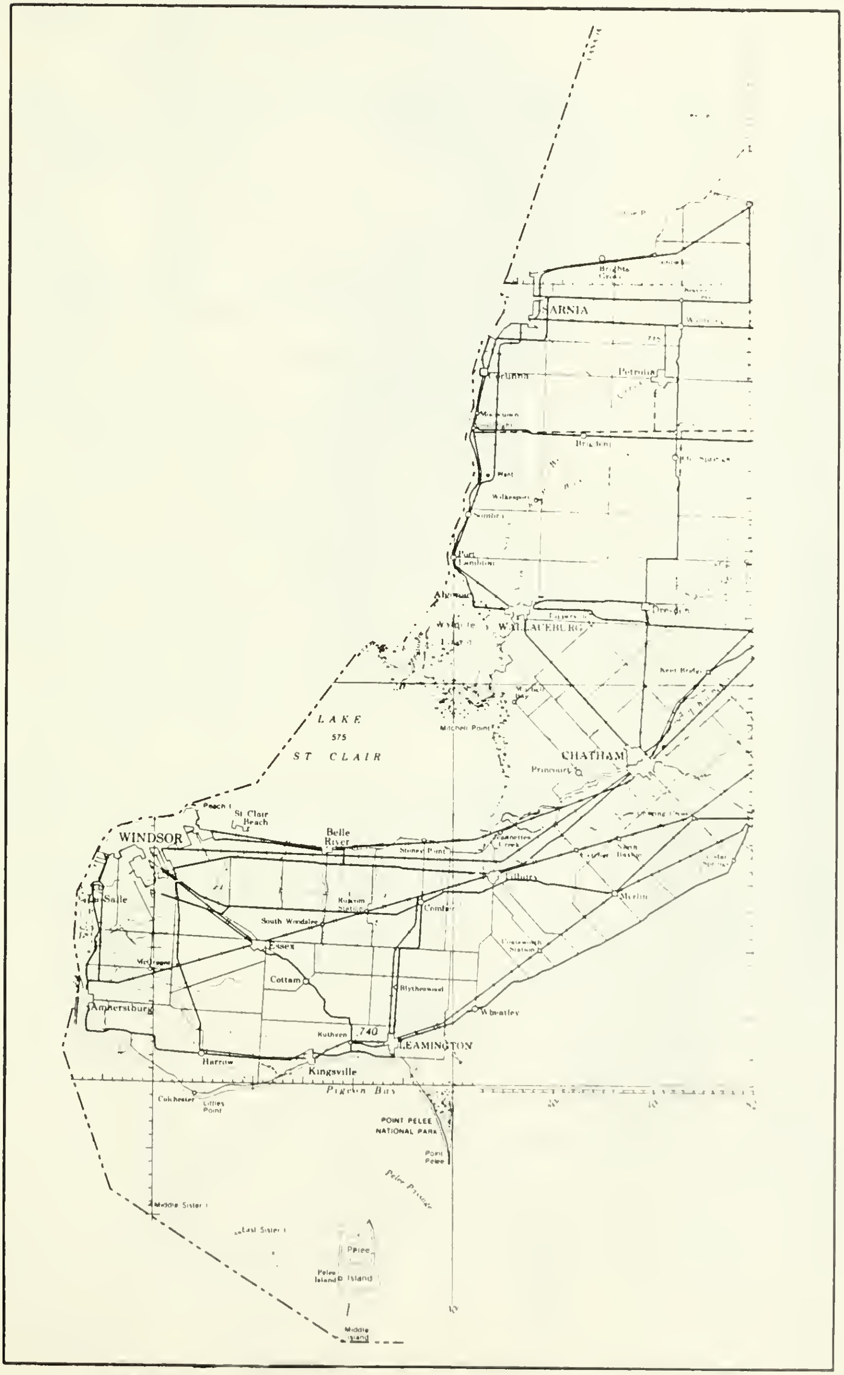


Figure 1.1 Sarnia-Windsor study area

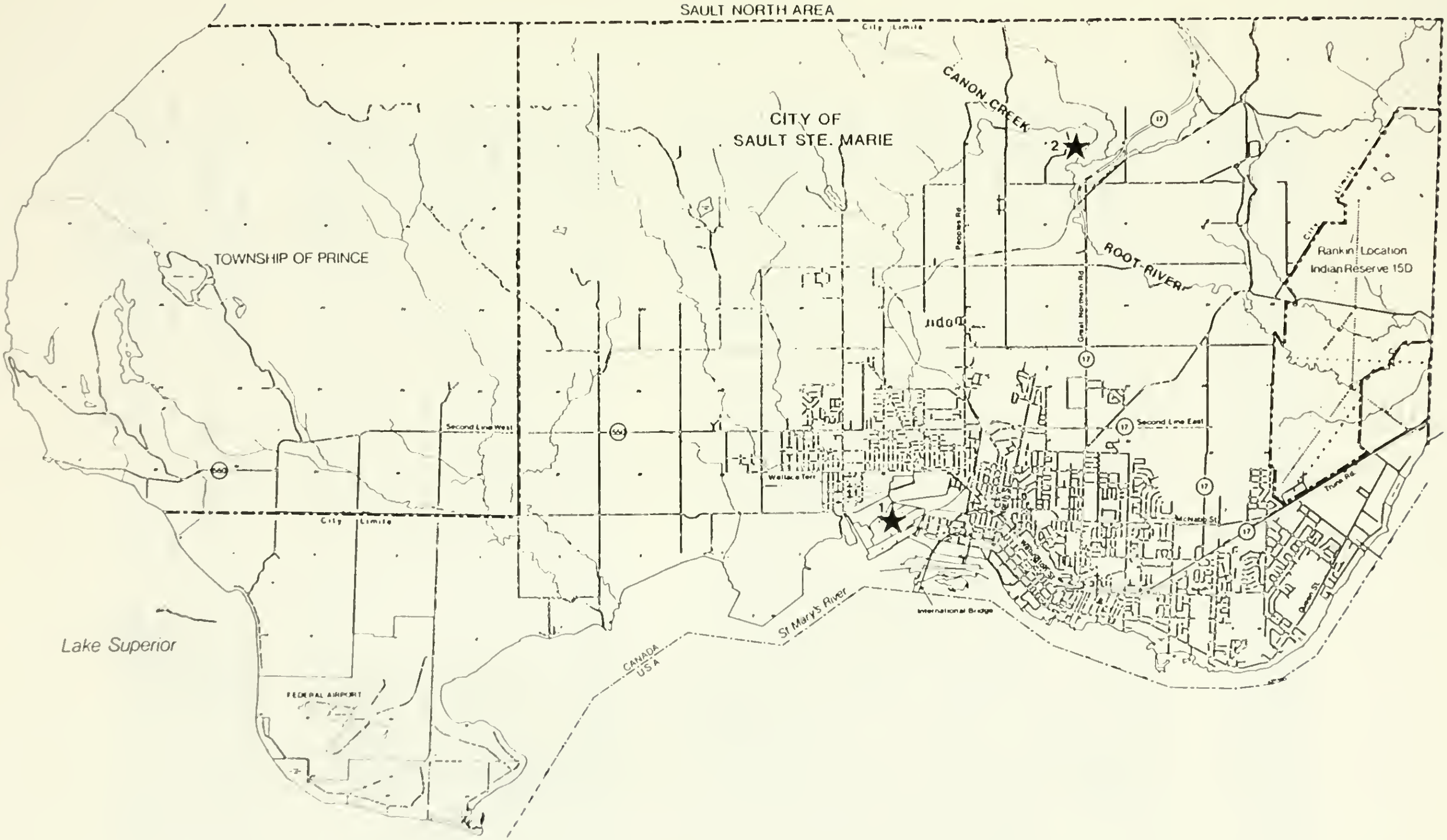


Figure 1.2 The Algoma District - Sault Ste. Marie study area showing:
1) Algoma Steel Corporation and
2) Sault Ste. Marie Landfill (from Dillon, 1984)

The report has been divided into two sections on study area characterization and monitoring programs (Section 2) and waste disposal sites inventory (Section 3).

Section 2 presents a detailed characterization of the study area, including regional studies of geology, physical environment (climate, hydrology, and soil types), hydrogeology, surface water quality, ground water quality and geochemistry, waste containment technologies, and contaminant transport and attenuation mechanisms. The purpose of the study area characterization is to provide the background information necessary to evaluate the potential environmental impact of each waste site in the study area. The geologic descriptions and reviews include all the sedimentary formations younger than Precambrian since the report is meant to provide a future reference document for deep well waste injection systems as well as the shallow waste sites addressed in the report.

Section 3 deals principally with the presentation of data pertinent to waste disposal sites with M.O.E Certificates of Approval and/or detailed site descriptions. Waste sites without M.O.E. Certificates of Approval or detailed site descriptions are discussed in the latter part of Section 3. In general, these sites are minimal in extent and are not expected to impact significantly on the water quality of the receiving water courses in the study area; however, possible exceptions to this are noted in Section 3.5.

Data compilations are presented on the master maps contained in Volume II. These maps contain the waste site locations and detailed information on the study areas characterization for the Sarnia-Windsor area. The maps comprise an integral part of this report.

In addition, discussions of contaminant transport and attenuation mechanisms are presented in appendices to the main body of the report.

2.0 STUDY AREA CHARACTERIZATION

The study area characterization is presented so that the geology, physical environment and hydrogeology of the region can be identified and so that the individual waste site can be placed into the regional characterization. This section attempts to bring together all the literature information pertinent to the characterization of the two study areas (with less emphasis on the Algoma District) so that it may act as a reference document for future studies and investigations.

2.1 Paleozoic Geology

In order to reduce the editorial burden of direct quoting and frequent referencing, much of the following review and descriptions of the geology and physiography of southern Ontario has been taken virtually directly from the reports by Sanford and Brady (1955), Sanford (1961), Winder (1961), Brigham (1971), Vandenberg et al., (1977), and Chapman and Putnam (1984). These authors are acknowledged here in addition to occasional referencing in the text. Although GTC personnel and others contributing to the report have conducted geologic and hydrogeologic studies in numerous specific parts of southern Ontario, these prime references are heavily relied upon for the regional geologic and structural framework and the physiographic summary of the region. The Sarnia-Windsor study is addressed in detail due to the abundance of published information on a number of waste sites, and the deep well waste disposal activities in the area. The Algoma District is addressed in less detail due to both the limited information base and limited number of waste sites, compared to the Sarnia-Windsor area.

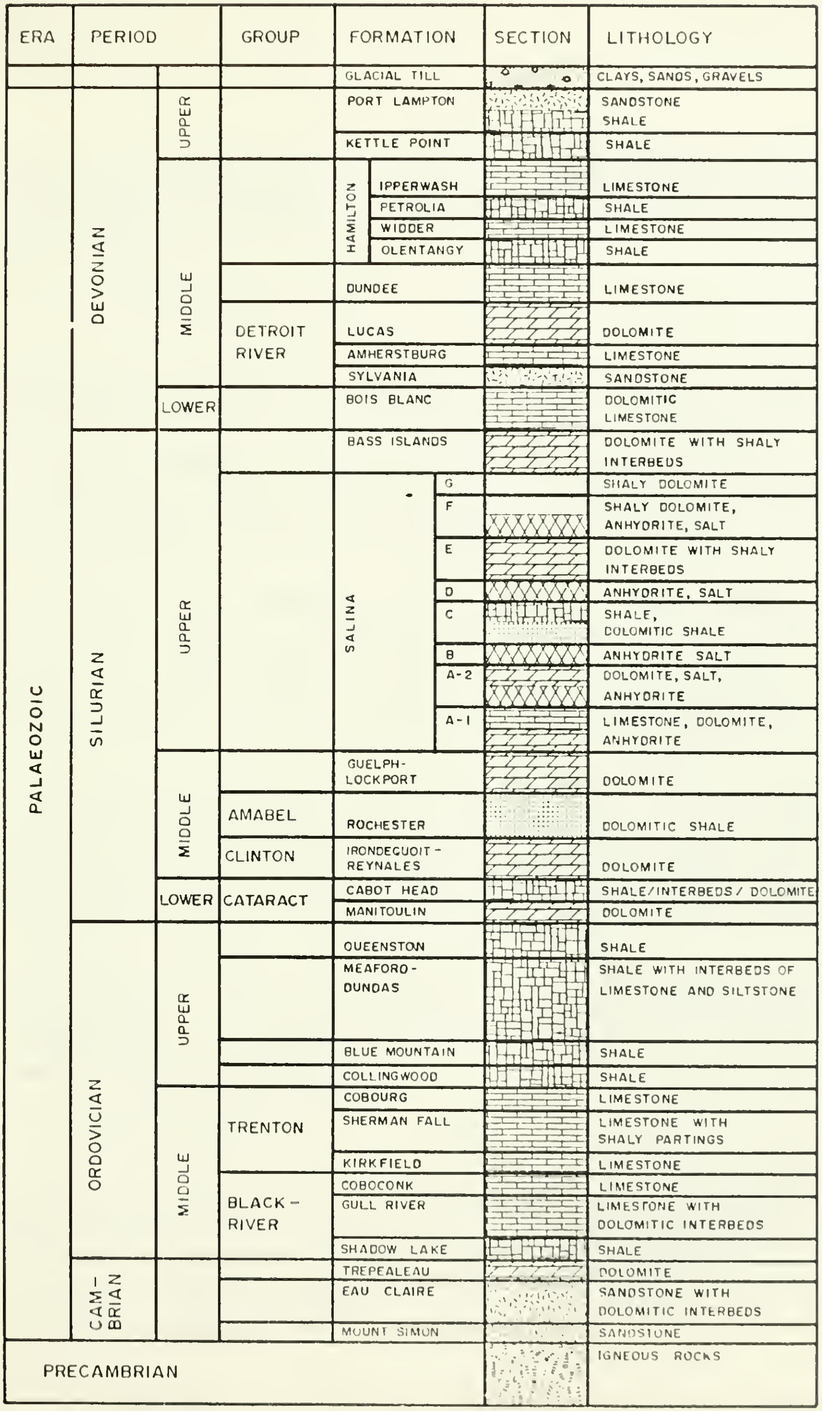
Southwestern Ontario, a shelf area throughout much of Paleozoic time, lies on the eastern rim of a Paleozoic age continental basin known as the Michigan Basin and on the northwestern flank of the Appalachian geosyncline. The barrier between these two areas of major deposition consists of two subsurface arches known as the Algonquin and Findlay Arches. The Algonquin Arch extends from the vicinity of Lake Simcoe southwestward to approximately Walpole Island in Lambton County where it meets the Findlay Arch which extends northeastward from Ohio. The Algonquin and Findlay Arches are separated by a synclinal depression often referred to as the "Chatham Sag" in central Kent County.

Sedimentary rocks underlying southwestern Ontario range in age from Cambrian to late Devonian and have a known thickness in excess of 1430 meters (Sanford, 1961). The beds gently dip to the southwest at approximately 0.0038 to 0.0057 m/m (Sanford and Brady, 1955).

Maps have been prepared showing the bedrock geologic formations and structure contours in the study area illustrated in Drawings 071-01-E, 071-01-K, and 071-01-L. Also, geologic cross sections, Drawings 071-02-1 and 071-02-2, were prepared to provide a full description of the continuity of the bedrock formations. These maps have been compiled from published reports and maps and examination of Ontario Ministry of the Environment well records.

2.1.1 Stratigraphy: Sarnia - Windsor Area

Figure 2.1.1 illustrates the Paleozoic stratigraphic column for Southwestern Ontario, focusing on the units identified within the study area. Rocks of Cambrian, Ordovician, Silurian and Devonian age are noted. The geologic cross sections through Essex and Kent Counties (Drawings 071-02-1 and



ERA	PERIOD		GROUP	FORMATION		SECTION	LITHOLOGY
				GLACIAL TILL			CLAYS, SANDS, GRAVELS
PALAEOZOIC	DEVONIAN	UPPER		PORT LAMPTON			SANDSTONE SHALE
				KETTLE POINT			SHALE
		MIDDLE		HAMILTON	IPPERWASH		LIMESTONE
					PETROLIA		SHALE
					WIDDER		LIMESTONE
					OLENTANGY		SHALE
				DUNDEE			LIMESTONE
			DETROIT RIVER	LUCAS			DOLOMITE
				AMHERSTBURG			LIMESTONE
				SYLVANIA			SANDSTONE
		LOWER		BOIS BLANC			DOLOMITIC LIMESTONE
	SILURIAN	UPPER		BASS ISLANDS			DOLOMITE WITH SHALY INTERBEDS
				SALINA	G		SHALY DOLOMITE
					F		SHALY DOLOMITE, ANHYDRITE, SALT
					E		DOLOMITE WITH SHALY INTERBEDS
					D		ANHYDRITE, SALT
					C		SHALE, DOLOMITIC SHALE
					B		ANHYDRITE SALT
					A-2		DOLOMITE, SALT, ANHYDRITE
					A-1		LIMESTONE, DOLOMITE, ANHYDRITE
		MIDDLE		GUELPH-LOCKPORT			DOLOMITE
			AMABEL	ROCHESTER			DOLOMITIC SHALE
			CLINTON	IRONDEQUOIT-REYNALES			DOLOMITE
		LOWER	CATARACT	CABOT HEAD			SHALE/INTERBEDS/DOLOMITE
				MANITOULIN			DOLOMITE
	ORDOVICIAN	UPPER		QUEENSTON			SHALE
				MEAFORD-DUNDAS			SHALE WITH INTERBEDS OF LIMESTONE AND SILTSTONE
				BLUE MOUNTAIN			SHALE
				COLLINGWOOD			SHALE
		MIDDLE	TRENTON	COBOURG			LIMESTONE
				SHERMAN FALL			LIMESTONE WITH SHALY PARTINGS
				KIRKFIELD			LIMESTONE
			BLACK-RIVER	COBOCONK			LIMESTONE
				GULL RIVER			LIMESTONE WITH DOLOMITIC INTERBEDS
				SHADOW LAKE			SHALE
	CAMBRIAN			TREPEALEAU			DOLOMITE
				EAU CLAIRE			SANDSTONE WITH DOLOMITIC INTERBEDS
				MOUNT SIMON			SANDSTONE
PRECAMBRIAN							IGNEOUS ROCKS

ADAPTED FROM McLEAN, 1968 AND BOOTH-HORST AND RYBANSKY, 1982.

Figure 2.1.1 Palaeozoic Stratigraphic Column for Southwestern Ontario

INTERA

072-02-2) outline the typical geologic formations present in the study area and indicates approximate thicknesses that have been observed.

2.1.1.1 Cambrian

The top of the Cambrian formations within the study area are located at depths up to 1300 m below ground surface. The upper Cambrian is approximately 57 meters thick (Sanford and Brady, 1955) and consist predominantly of the Mount Simon, Eau Claire and Trempealeau Formations.

The Mount Simon Formation constitutes the oldest Upper Cambrian strata in southwestern Ontario. Very few wells penetrate these rocks but, where observed in cuttings, the beds consist of white to light grey quartzose sandstone.

The Eau Claire Formation overlies the Mount Simon stratigraphically and within the study area it is composed of fine to medium grained sandstone, containing angular to sub-angular quartz grains, with interbeds of grey, finely crystalline dolomite and grey shaly dolomite.

The uppermost Cambrian Formation in the study area is the Trempealeau. It consists of buff to grey-buff, fine to medium crystalline dolomite.

2.1.1.2 Ordovician

The top of the Ordovician is found at a depth of approximately 900 meters at Sarnia and at approximately 425 meters in Essex County (Sanford and Brady, 1955) with a total thickness averaging about 490 meters.

The oldest Ordovician strata are those of the Black-River group of Middle Ordovician age. They are, in ascending order, a green or occasionally red dolomitic and sandy or silty shale, greenish grey shaly and silty dolomite, with occasional brown lithographic limestone interbeds (Shadow Lake Formation); brown to buff-brown and cream coloured lithographic limestone containing minor interbeds of finely crystalline and brown granular to crystalline dolomite (Gulf River Formation); and buff to buff-brown and tan coloured, finely crystalline to granular, limestone with a thin zone of fragmental limestone at the top of the formation (Coboconk Formation). The overall thickness of the Black River Group varies from about 120 to 150 meters throughout the study area.

Lying disconformably above the Black-River Group and varying lithologically is the Trenton Group. The Trenton Group, as defined by Sanford (1961), consists of the Kirkfield, Sherman Fall and Cobourg Formations.

The Kirkfield Formation consists of a greyish brown finely crystalline limestone at the top, alternating with grey and grey-buff fragmental limestone and grading downward to dark grey, fragmental, carbonaceous and shaly limestone and shale at the base.

Overlying the Kirkfield, the Sherman Falls Formation consists of grey to grey buff, finely crystalline to fragmental limestone, containing abundant shale partings and interbedded dark grey shale. In certain places the differences between the two formations cannot be readily distinguished and therefore they are logged as a single unit.

The uppermost Trenton Group unit is the Cobourg Formation. This formation consists of dark brown to dark greyish brown, finely crystalline limestone containing a few shale partings and occasional fragmental limestone interbeds at its lower part. The overall thickness of the Trenton Group varies, averaging approximately 150 meters in the Sarnia area, decreasing to 100 meters in the southern part of Essex County.

Overlying the Trenton Group, is a dark brownish grey to black, fissile, bituminous shale, commonly referred to as the Collingwood Formation. It is in sharp contact with the underlying brown Trenton limestone and varies in thickness from 30 to 60 meters.

The overlying Blue Mountain Formation consists of grey to dark grey, soft fissile shale containing occasional thin laminations of grey argillaceous and silty limestone. Due to the similarity of this formation to the overlying Meaford-Dundas, it is extremely difficult to separate the two formations in the subsurface, in which case they are logged as a single unit.

The Meaford-Dundas Formation consists of a succession of shales with interbeds of limestone and calcareous siltstone. The shales are typically greenish grey at the top and predominantly dark grey near the base. The total thickness varies from 58 to 145 meters.

The youngest Ordovician strata overlying the Meaford-Dundas Formation in the study area is the Queenston Formation. It consists of red shale with interbeds of green shale and grey to greenish grey, argillaceous limestone varying in thickness from 70 to 95 meters. Mottled red and green shale is common.

2.1.1.3 Silurian

Next in succession, overlying the Ordovician strata, are rocks of Silurian age, consisting of, in order from oldest to youngest, the Cataract, Clinton and Amabel Groups, overlain by the Guelph-Lockport, Salina and Bass Island Formations. The top of the Silurian occurs at a depth of approximately 335 meters and has a total thickness of 580 meters in Lambton County. In Essex County the top of the Silurian occurs at a depth of approximately 120 meters.

The oldest Silurian rock is the Manitoulin Formation of the Cataract Group. This formation consists of a grey dolomite and argillaceous dolomite with minor greenish grey shale interbeds. The thickness varies from 15 to 24 meters. The Silurian-Ordovician boundary is marked by the distinct contrast between the red shale of the Queenston Formation and the dolomite of the Manitoulin Formation.

The upper strata of the Cataract Group is known as the Cabot Head Formation and consists of greenish grey, green and red shales with interbeds of grey argillaceous dolomite. It varies from 18 to 30 meters in thickness.

Overlying the Cataract Group and considered Middle Silurian in age, are two formations, the Irondequoit and Reynales, commonly known as the Clinton Group. The strata basically consist of buff to grey, fine to medium, crystalline dolomite. Within the study area, it is not possible to differentiate between the two formations because the contact between the two cannot be identified in well cuttings and therefore they are considered a single unit. The thickness of the formation varies from 0.6 to 6 meters (Sanford and Brady, 1955).

The Amabel Group, Rochester Formation, overlies the Clinton Group and consists of dark grey dolomitic shale with interbeds of grey, shaly dolomite. Sanford and Brady (1955) note that the thickness varies from 3 to 15 meters.

The next formation, the Guelph-Lockport, consists of medium to coarsely crystalline dolomite varying in thickness from 26 meters in Lambton County to 152 meters in parts of Essex County. Also found in the Guelph-Lockport Formation are small, pinnacle-like, bioherm reefs that may extend into the overlying Salina Formation to a height of over 122 meters (Sanford and Brady, 1955).

The Salina Formation is comprised of several different distinct stratigraphic beds and is subdivided into seven units designated A to G (Figure 2.1.1), A being the oldest. The formation consists predominantly of a grey, argillaceous dolomite overlying a grey to greenish grey, dolomitic shale, overlying a brown to buff, finely crystalline dolomite with a brown to greyish brown limestone near the base. Anhydrite is common throughout the formation and several salt beds are also evident. The overall thickness of the formation has been reported to approach 197 meters (Sanford and Brady, 1955).

Overlying the Salina Formation is the Bass Island Formation which is the youngest Silurian strata in the area. It consists of buff to brown, finely crystalline, oolitic dolomite. The thickness varies locally from 18 meters to a maximum of 120 meters indicating a period of erosion at the end of Silurian time. These rocks subcrop in a small area in the southwestern corner of the study area in Colchester South Township, Essex County (Drawing 071-01-E) and continue to subcrop to the south and southwest under Lake Erie.

2.1.1.4 Devonian

The majority of the bedrock subcropping in the study area are of Devonian age and consist of in ascending order; Detroit River Group, Dundee Formation, Hamilton Formation, Kettle Point Formation and the Port Lambton beds. Underlying the Detroit River Group is one other Devonian age formation, the Bois Blanc Formation. The formation has been identified but does not subcrop anywhere within the study area.

The Bois Blanc Formation consists of brown and grey, fine to medium grained, dolomitic limestone or calcareous dolomite with abundant chert. The extent of the formation within the study area is vague, however, it appears to thin out gradually southward and tends to be nonexistent in parts of Essex County.

Overlying the Bois Blanc Formation and, where the former is absent, the Bass Island Formation are the dolomite, limestone and sandstone units of the Detroit River Group. These units underlie the unconsolidated deposits in the southwestern part of Essex County, roughly south of a line between Amherstburg, Essex and Leamington and along a one to three kilometer wide strip adjacent to the Detroit River from Amherstburg to Windsor. (Drawing 071-01-E).

The sandstone unit, known as the Sylvania Sandstone rests disconformably on the erosional surface of the underlying Bass Island Formation. The Sylvania Sandstone is comprised of large, rounded and frosted, and loosely cemented quartz grains with associated glauconite. Winder (1961) notes that the maximum thickness is 38 meters but occurrences are usually less. The formation is evident in a small area south of Amherstburg adjacent to the Bass Island Formation subcropping.

Overlying the Sylvania Sandstone unit is the yellowish brown, fine grained petroliferous limestone Amherstburg Formation. This formation is found in the southern part of Essex County, south of Amherstburg.

Overlying the Amherstburg Formation is the final Detroit River Group Unit, the dolomitic Lucas Formation. This formation is characterized by a lighter colour and the presence of anhydrite in the subsurface. The total thickness of the Detroit River Group is approximately 180 meters (Sanford and Brady, 1955).

Limestone belonging to the Dundee Formation rests directly on the Detroit River Group (Drawing 071-01-E). The limestone in this formation is described as buff coloured, fine grained clastic limestone in the lower part becoming finely crystalline above. Quartz grains and light grey chert are common at the base and small amber-coloured spore cases are present throughout the formation. It varies in thickness from 26 to over 49 meters (Sanford and Brady, 1955).

The Hamilton Formation overlies the Dundee Formation and occurs in the area between Windsor and Belle River in Maidstone Township, Essex County, (Drawing 071-01-E) in the southwestern corner of Kent County, (Drawing 071-01-K) as well as several large sections in Lambton County (Drawing 071-01-L). The formation has been subdivided into four members known in ascending order as; Olentangy shale, Widder beds, Petrolia shale and Ipperwash limestone. The Olentangy and Petrolia members are soft light grey calcareous shales with the Olentangy varying in thickness from 8 to 30 meters and the Petrolia ranging from 21 to 58 meters. Occasional limestone interbeds occur within the shales and in many places at the base of the Olentangy there is a 1.5 to 3 meter

bed of grey limestone. The Widder beds are described as a fine to medium crystalline argillaceous limestone from 1.5 to 6 meters thick lying between the two shale members. The uppermost member in the formation is the Ipperwash limestone which is described as a grey, fine grained, argillaceous limestone with minor interbeds of crystalline limestone, approximately 6 to 40 meters in total thickness (Sanford and Brady, 1955). The combined thickness of the four members may total over 90 meters. However, all members vary in thickness from one locality to another and cannot always be recognized in well cuttings.

Overlying the Hamilton Formation and subcropping through the majority of Kent and Lambton Counties is the Kettle Point Formation (Drawings 071-01-K and 071-01-L). This formation is a dark brown to black, bituminous shale with occasional interbeds of green shale. The thickness varies from a few meters to in excess of 100 meters (Sanford and Brady, 1955).

The youngest formation found within the study area occurs along the St. Clair River from Port Lambton north through Sombra Township into Moore Township (Drawing 071-01-L). This formation referred to as the Port Lambton beds, consists of soft light grey, micaceous, very fissile shale interbedded with siltstone overlain by a light grey, very fine grained, micaceous sandstone. In some localities the lower shale member is absent and the sandstone occurs directly above the Kettle Point. The shale and sandstone together vary in thickness from a few meters to 60 meters or more (Sanford and Brady, 1955).

2.1.2 Structure

In the subsurface of southwestern Ontario, some local doming, anticlinal structures and some possible faulting has been identified. Displacements of basement rock are evident on structure maps of the Precambrian surface, however, they tend to be clearly defined on the Middle Ordovician Trenton surface due to the greater number of control points (Brigham, 1971). Nonetheless, adequate numbers of well controls do not exist to identify localized small structures although many are believed to exist (Sanford, 1961) and often it is not known whether an apparent offset in the basement surface or the Trenton surface is a monocline or a fault due to the lack of well control near the feature.

Within the study area only a few structures (Figure 2.1.2) have been identified. One is a narrow westward extension of the Algonquin arch through Zone, Camden, Chatham and Dover East Townships, near the Kent-Lambton County line. Where this structure appears most prominant, rocks of the Trenton Group dip northwestward at the rate of about 0.00072 m/m. To the south the beds appear to drop off at approximately a five degree slope (Sanford, 1961). An east-west trending fault known as the Electric Fault controls this structure.

Other smaller displacements that have been identified are the Kimball-Collinville Monocline south of Kimball in Moore Township, the Dawn structure in north central Dawn Township and an unnamed structure in south-central Enniskillen Township. These deep structures generally have gentle, relatively featureless dips that outline the major structural arches (Algonquin and Findlay), sags and basins. The features tend to become obscured or are not evident on structural maps of Devonian horizons due to later deposition over the fault or monocline.

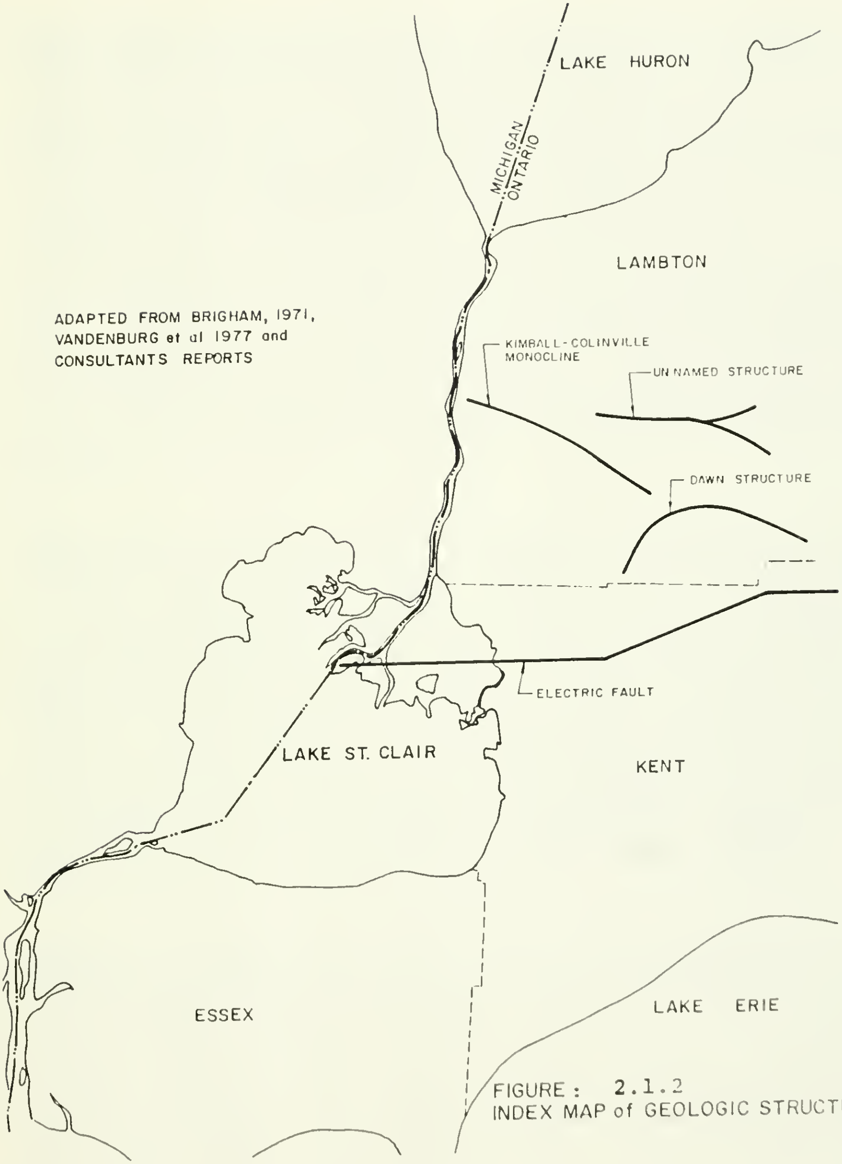


FIGURE : 2.1.2
INDEX MAP of GEOLOGIC STRUCTURES

Other local disruptions of the continuity of the original depositional bedding that have been identified are those due to reefal features and the dissolution of Silurian salt. Carbonate mounds known as pinnacle reefs have been identified in a 16 to 32 km wide trend near the southern end of Lake Huron (Brigham, 1971). The base of the mounds are in the Guelph-Lockport Formation and may extend into the overlying Salina Formation to a height of 122 meters (Sanford and Brady, 1955). Many of the reefs are oil and gas producers and have good permeability and porosity. However, Brigham (1971) notes that north of an east-west line through central Lambton County, the porosity is greatly decreased due to plugging of the pores by salt.

Dissolution of Silurian salt has produced irregularities in the thickness and structure of young deposits. The most extensive leaching, particularly in Kent and Essex Counties, occurred during Upper Silurian (Bass Island) time and continued into Lower Devonian time (Sanford, 1965). Initial leaching began along the inner margin of a carbonate bank surrounding the Michigan Basin and above the bioherm reefs mentioned above. This resulted in a karst-like bottom topography with cavities on the sea-floor 90 to 122 meters in depth that gradually became filled with carbonate of the Bass Island Formation.

During post Upper Devonian time large scale dissolution and subsequent collapse took place in areas in northern Kent County and the adjacent region of Lambton. Salts above many of the pinnacle reefs were removed by solution resulting in a major collapse of the overlying Devonian strata. There are also numerous concentric and elongated collapse structures, some of which occur above small incipient bioherm reefs and others that have resulted from leaching along major joints or fault planes.

2.1.3 Stratigraphy: Algoma District

The bedrock geology of the Algoma District is similar to the bedrock geology of the Sarnia-Windsor area in that it is also found on the northern edge of the Michigan Basin. The sedimentary sequences that lie on top of the Precambrian crystalline basement consist of red and grey sandstone and are likely Cambrian or Ordivician in age. The sandstone lie unconformably on the crystalline basement rock which rises to the surface at a distance of about eight kilometers from the St. Mary's River. The thickness of the sandstone is unknown and the depth to bedrock is variable. In the Sault Ste. Marie area the sandstone bedrock forms two high domes which rise close to the surface. This fact results in deep overburden basins located adjacent to the domes.

2.2 Surficial Geology

Sarnia-Windsor Area

The unconsolidated sediments and surface features present in the Sarnia-Windsor study area are the result of glacial and post glacial processes. During the Pleistocene epoch, Southern Ontario was inundated by at least four distinct continental ice sheets, the Wisconsinan being the last glacial period to affect the study area. For a comprehensive outline of the glacial and post glacial development in Southern Ontario the reader is referred to Chapman and Putnam (1984).

The unconsolidated materials overlying the bedrock in Southern Ontario consist mainly of sheets of till laid down directly by the ice, glaciofluvial deposits (i.e., sand and gravel deposited by streams of water draining from the melting glacier) and clays, silts and sands deposited in lakes which existed during the

recession of the glacier. Generally, the till deposits are overlain by the glaciofluvial deposits which in turn are overlain by the glaciolacustrine deposits. More recent deposits from present day streams and lakes are uppermost and are still in the process of being developed.

At its maximum the Wisconsinan glacier covered all of Ontario and extended to Southern Ohio. It was not until it had receeded and uncovered all of Ohio that the first land was uncovered in Southern Ontario. The retreat of the glacier was not simply an uncovering of the land from south to north but consisted of several lobes that split apart, first near Orangeville or Waterloo, with the area under study still covered by the glacier. The two ice lobes, the Huron lobe to the north and the Erie lobe to the south continued to split until the study area was uncovered. As the lobes split, several small moraines, the Leamington, Blenheim and Charing Cross, found in the southern part of the study area, were formed. Also, as the lobes split, the channel flow was directed southwest producing glacial Lake Maumee which covered the present day Counties of Essex and Kent. As the Huron lobe continued to receed it uncovered a valley west of Ubly, Michigan, which allowed the lake in front to fall 18 meters. Continued withdrawal uncovered another outlet 9 to 12 meters below the one at Ubly further lowering the lake. Readvancement of the Huron lobe subsequently closed the later outlet which caused the lake level to again rise up to that of the Ubly outlet, thereby establishing Lake Whittlesey, the next major glacial lake to cover the study area.

During the time of Lake Whittlesey the Huron lobe built the Wyoming Moraine, part of which is found in Lambton County. Lake Whittlesey gave way to Lake Warren and then Lake Lundy as the glacier retreated and new outlets were opened. Each of these glacial lakes had an influence on the surficial deposits

in the study area that will be discussed in a subsequent section. Following Lake Lundy there was a period when a lake, Lake Algonquin, covered the flat plain around Lake St. Clair. A low but distinct bluff of thin beach strand at 184 meters a.s.l. (Chapman and Putnam, 1984) marks its shore from Dresden to Sombra. At this point in time the drainage flowed northward through the St. Clair River channel into Early Lake Algonquin. This was the last glacial lake to influence the study area.

Following the retreat of the glacier, post glacial processes, namely erosion and deposition operated (and still operate) to further alter and influence the present surficial deposits. In the wet and undrained depressions, bog plants have flourished and have accumulated, eventually producing peat bogs.

2.2.1 Sarnia-Windsor Study Area

The surficial deposits and surface features present in the study area are predominately due to the glacial lakes just discussed that inundated the area during the glacial period. Maps showing surficial geology of the study area (Drawings 071-03-E, 071-03-K and 071-03-L) and thickness of unconsolidated deposits over the bedrock (Drawings 071-04-E, 071-04-K and 071-04-L) were produced. These maps have been compiled based primarily on geologic information available from published reports and maps and examination of Ontario Ministry of the Environment water well records.

Within the study area there are predominantly four physiographic regions as outlined by Chapman and Putnam (1984). They are:

1) St. Clair Clay Plains;
2) Bothwell Sand Plains;
3) Horseshoe Moraines- Wyoming Moraine; and
4) Huron Fringe.

2.2.1.1 St. Clair Clay Plains

The St. Clair Clay Plains cover the majority of the study area. The region is relatively flat with little relief, lying between 175 and 213 meters a.s.l. (Chapman and Putnam, 1984) except for the moraines at Ridgetown and Blenheim (Charing Cross and Blenheim Moraines) which rise 15 to 30 meters higher. A thick covering of overburden, sometimes in excess of 61 meters is found in the area.

Glacial Lake Whittlesey and Lake Warren which deeply covered the study area failed to leave deep stratified beds of sediment on the underlying clay till except around Chatham, between Blenheim and the Rondeau marshes and a few other smaller areas. Most of Lambton and Essex Counties are therefore essentially till plains smoothed by shallow deposits of lacustrine clay which settled in the depressions while the knolls were being lowered by wave action. The very flat land east of Lake St. Clair and predominantly in Kent County was submerged after the disappearance of Lake Warren by a correlative of Early Lake Algonquin and received a deeper covering of stratified clay and silt.

In Essex County and the southwestern part of Kent County the surficial deposits are primarily a till overlying a low swell in the bedrock. The prevailing soil is described as a Brookston clay loam (Richards et al., 1949); a dark surfaced clay loam over mottled and blue grey gritty clay and clay loam.

Also found in this area are several features which are somewhat atypical of the region. One of these, the Blenheim Moraine, is a modest ridge of rolling clay land rising 15 to 30 meters above the surrounding plain. It is fringed by gravel terraces which meet at Blenheim and continue southwest through Cedar Springs to the shore of Lake Erie.

Another small morainic hill can be found near Leamington. This moraine, composed of sand and gravel, was smoothed down by the action of Lake Whittlesey and Warren and surrounded by a series of gravel beaches. Also, down the slope toward Lake Erie, broad aprons of fine sand and silt can be noted.

Another area of sandy soil is found surrounding Harrow. This area was not high enough to form an island in Lake Warren and therefore is regarded as a group of shallow water sand bars. The flatness of the Essex clay plain is further broken by a gravel ridge extending through Essex, Cottam and Maidstone. Similar gravel strands are found at Pelton and shallow gravel deposits occur near Edgars, Gesto and Comet.

The surficial deposits of the St. Clair clay plain in Lambton County is very similar to that of Essex County. The area is a bevelled till plain often having a shallow veneer of lacustrine clay over the underlying till. The main soil types here are Brookston clay and Caistor clay, the former in the lower, wetter sites and the latter on the higher sites.

Two distinct till units are recognizable (Fitzgerald et al., 1979) in this area. These units were not differentiated in Drawing 071-03-L, however, the difference deserves mention. The region to the south of Courtright consists of a clayey to sandy silt till with abundant black shale clasts, frequent Devonian megafauna and occasional gypsum crystals.

The till is commonly referred to as Black Shale Till. The unit stratigraphically above the Black Shale Till and the predominant surficial deposit north of Courtright is known as St. Joseph Till. This unit differs from the Black Shale Till in that the shale content is much lower and fewer megafauna are encountered. The significance of the two units is that they are separated by a massive to laminated, sometimes contorted, lacustrine sandy silt to clay which suggests an erosional unconformity.

The flat land east of Lake St. Clair in Dover and Chatham Townships in Kent County was submerged by a correlative of Early Lake Algonquin and therefore has a deeper covering of lacustrine clays. The Chatham Flats are bounded in the north by a low but distinct bluff just above the 180 meter contour (Chapman and Putnam, 1984). Beyond the bluff the clay plain also has very little relief but it lacks the deep lacustrine clays just mentioned. In Chatham Township a shallow surface layer of sand on the clay is prevalent and immediately south and east of the City of Chatham beds of silt can be noted. In Dover Township the stratified clay or loam comes right to the surface except where a few sand spots or black muck occur. Detailed investigations of representative tills throughout the St. Clair clay plain have been reported by Quigley and Ogunbadejo (1976), Goodall and Quigley (1977) and Desaulniers et al. (1981). Other studies have been conducted by Hanna (1966), Soderman and Kim (1970) and Fitzgerald et al., (1979). Site specific testing of tills by consultants has also been done at more than ten industrial or municipal waste disposal sites. Generally, the studies suggest the tills are typically 40 to 60% clay and contain abundant carbonate, quartz, feldspars and shale fragments from the regional bedrock formations.

2.2.1.2 Bothwell Sand Plain

The sand plain divided by the Thames River and found predominantly in the northeastern part of Kent County extending towards Chatham is known in the Bothwell Sand Plain. The Bothwell Sand Plain is the delta of the Thames River in glacial Lake Warren and stands between 180 and 210 meters a.s.l. (Chapman and Putnam, 1984). The glaciolacustrine deposits in the plain are basically sands, silts and minor gravels which overlie the clay below. The deposits are approximately one meter thick. Water tends to collect above the clay since precipitation easily infiltrates the sandy surface but percolates slowly through the clay below. This causes a high local water table and therefore the depressions tend to be swampy.

2.2.1.3 Horseshoe Moraines - Wyoming Moraine

Extending from Bruce County to Lambton County are a series of moraines in a horseshoe shaped pattern that belong to the Port Huron Moraine system. The only one that impacts the study area is the Wyoming Moraine which is found in Lambton County from Alisa Craig (just outside the northeast corner of the study area) southward, this section of the Wyoming Moraine was built into the waters of Lake Whittlesey and forms a single broad ridge which fades out west of Wyoming. The soils in the moraine are described as a clay till. On the slopes of the moraine, Lake Warren glaciolacustrine deposits of sand, silt and minor gravel are evident.

2.2.1.4 Huron Fringe

Along the shore of Lake Huron and adjacent and below the St. Clair clay plains is a narrow strip of land known as the Huron Fringe. The Huron Fringe extends from Sarnia to

Tobermory in Bruce County, but the area of concern as pertaining to this study only extends to Kettle Point from Sarnia. The fringe is comprised of wave cut terraces of glacial Lake Algonquin and the subsequent Lake Nipissing. The deposits are primarily glaciolacustrine boulders, gravel bars and sand dunes.

At Kettle Point a shelf of bedrock (Kettle Point Formation) which has not yet been worn away is evident. It stands uncovered and large round concretions, called kettles are exposed.

From Brights Grove to Sarnia, sandy beaches along the shore protect a large marshy area of peat and muck, which until recently was a marsh. This area has been drained and is presently under cultivation.

2.2.2 Algoma District Study Area

The overburden geology of the Algoma District consists of sand and gravel near the basement upland and clay till near the St. Mary's River. The sand and gravel butts up against the southern edge of the basement uplands but gradually pinches out towards the south or remains as a layer overlying the sandstone bedrock. The dominant overburden material is a brown clay which in some places is in excess of 120 metres thick. The clay sequences are sometimes associated and interbedded with the sand and gravel found to the north. The clay sequences have been referred to as till and in places bears similar characteristics to a till. It has also been referred to (Gartner Lee Associates, 1983) as glacial sand till, silty sand till, sandy silt till and clayey sand till in the area of the Sault Ste. Marie Landfill (Cherokee) Site.

2.3 Physical Environment

This section will provide a general overview of the climate, hydrology and major soil groups of the study area. The drainage monitoring network, solids transport and loading, storm hydrograph analysis and concentration/discharge relationships will be discussed and their significance in assessing impact on receiving water bodies will be noted.

2.3.1 Climate

The Southwestern section of Ontario that is included in the study area is comprised of three climatic regions. The Kent and Essex Region covers most of Kent and Essex Counties. The Lake Erie Counties Region covers the majority of Lambton County. The Northern tip of Lambton County above Sarnia is within the Lake Huron Climatic region. The District of Algoma is within the Sudbury Climatic Region.

2.3.1.1 Temperature

The January mean daily temperature (MDT) for Kent and Essex Counties is -4 to -3 °C. For Lambton County, the January MDT is -4°C whereas for July the area bordering Lake Huron has a MDT of 20°C and the remaining area has an MDT of 21-22°C.

The average temperatures found in Southwestern Ontario (Figure 2.3.1) are regulated to a certain extent by the local presence of the Lake Huron to Lambton County and Lake Erie to Kent and Essex Counties. That part of Lambton County adjacent to Lake Huron experiences a 1°C higher January MDT than the interior (East of London, Ontario).

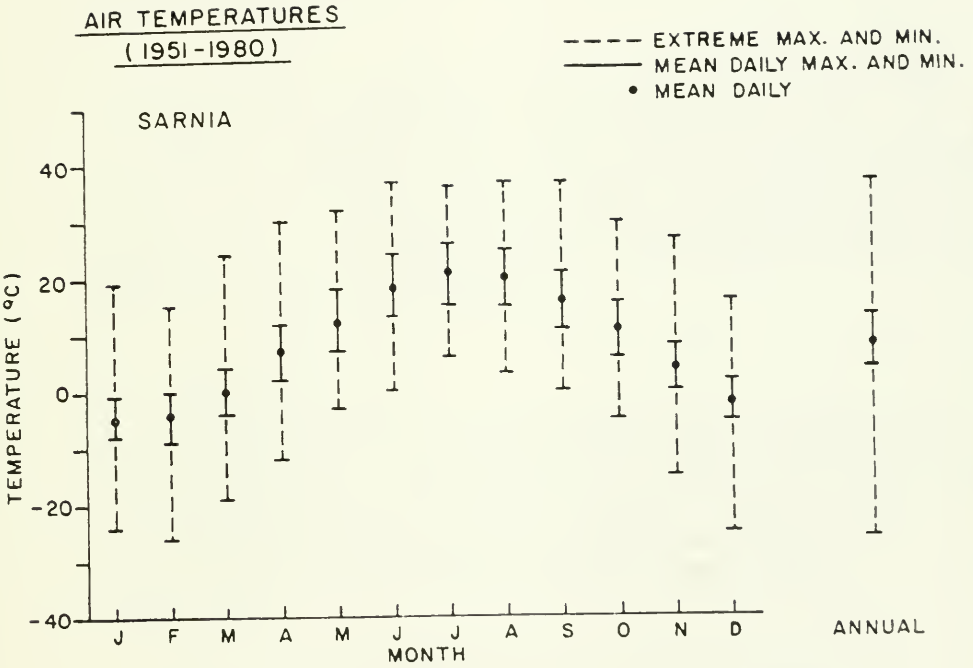


Figure 2.3.1 Representative Air Temperatures - Sarnia-Windsor Area

The July MDT for Kent and Essex Counties is 1-2°C cooler than the interior and for the north shore of Lambton County the July MDT is 1°C cooler than the remainder of the County. The presence of Lake Huron and Lake Erie thus tend to warm the Kent, Essex, and Lambton Counties above the interior MDT both in winter and summer by 1-2°C. The monthly air temperature data for Sarnia as shown in Figure 2.3.1.

The January MDT for Algoma District range from -3°C in the interior to -8°C for the area around Sault Ste. Marie. The July MDT for Algoma District ranges from 17°C in the interior to 19°C for Sault Ste. Marie and Southern Ontario. Again the presence of Lake Superior and the North Channel moderates the temperatures of the Algoma District especially the shore line adjacent to the North Channel.

2.3.1.2 Precipitation

The mean precipitation across Southern Ontario ranges from about 66 to 100 cm. This variation is closely related to the slope and elevation of the land location relative to the Great Lakes and prevailing wind direction. Monthly precipitation data for Sarnia (Lambton) is shown in Figure 2.3.2.

A summary of the pertinent climatic data is presented in Table 2.3.1.

2.3.2. Surface Hydrology

2.3.2.1 Drainage Systems

The surface water drainage pattern for the study area is shown in maps 071-05-L, 071-05-K and 071-05-E.

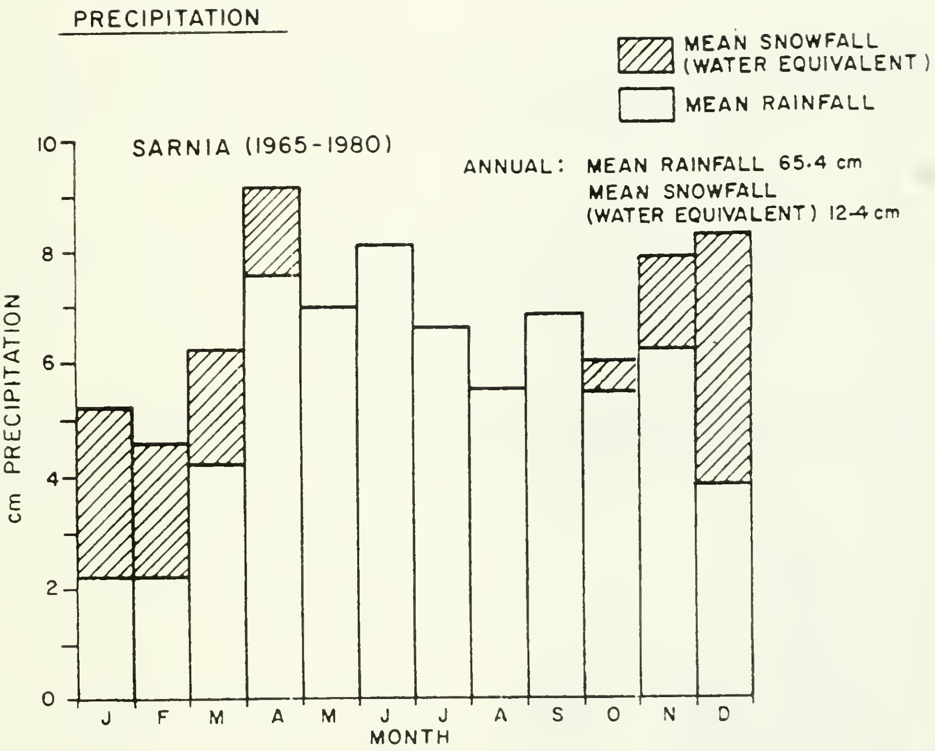


Figure 2.3.2 Representative Precipitation - Sarnia-Windsor Area

Table 2.3.1 Regional Climates of Study Area

Climatic Region	Leamington	Kent and Essex	Lake Erie Counties	Sudbury North Bay Sault Ste. Marie
Altitude (feet above sea level)	600	600	700	600-1000
Mean Annual Temperature °F	49	48	47	40
Mean Daily Maximum Temperature °F				
- January	32	31	31	22
- April	55	55	53	48
- July	81	82	81	77
- October	62	61	61	54
Mean Daily Minimum Temperature °F				
- January	20	19	17	2
- April	37	36	35	28
- July	64	62	59	54
- October	45	43	41	36
Daily Range of Temperature °F				
- January	11	12	13	
- July	17	20	21	23
Extreme Low Temperature °F	-20	-27	-34	
Extreme High Temperature °F	105	106	106	
Mean Date of Last Frost in Spring	May 1	May 5	May 12	May 31
Mean Date of First Frost in Fall	Oct 20	Oct 15	Oct 10	Sept 20
Mean Annual Frost Free Period (Days)	170	165	150	112
Start of Growing Season	Apr 6	Apr 8	Apr 10	Apr 25
End of Growing Season	Nov 12	Nov 11	Nov 8	Oct 24
Mean Annual Length of Growing Season	220	215	210	183
Mean Annual Growing Degree-Days	4200	4100	3700	2800
Mean Annual Precipitation (inches)	30	34	34	33
Mean Annual Snowfall (inches)	35	40	50	85
Mean Annual Potential Evapotranspiration (inches)	26	26	25	22
Mean Annual Actual Evapotranspiration (inches)	22	21	22	21
Mean Annual Moisture Defieciency (inches)	4	5	3	1
Mean Annual Water Surplus (inches)	9	10	13	13
Mean Annual Runoff (inches)	9	8-9	10-11	15

Note: Most data in this table are based on 30 to 50 years of record, however those indicated with an * began in 1944.

The study area was subdivided into terminal basin and watershed boundaries.

The network monitoring system used in the streamflow and storm hydrograph analysis is shown in Figure 2.3.3.

2.3.2.2 Streamflow and Transport

The streamflow and transport characteristics of the Canard, Ruscom and Sydenham Rivers and Bear Creek catchment areas were analyzed to determine the potential impact that surface run-off would have on the St. Clair, St. Mary's and Detroit Rivers through the transport of materials from the catchment areas. The flow rate, dissolved and suspended solids levels, annual water balance and storm event data were collected and analyzed for the years 1979 and 1983. The monthly mean flow rate data were analyzed from 1967-1982 where available. The daily flow rate data were taken from published Surface Water Data by Environment Canada. The water quality data were taken from the published Water Quality Data Series by Ministry of the Environment. The rainfall input data were taken from daily precipitation totals supplied by the Atmospheric Environment Service for the study area.

The monthly suspended and dissolved solids levels were the only transport quantities investigated here. These figures were cross-referenced to their corresponding streamflow data by identification with the respective sampling and monitoring station. The sampling stations identified in the Environment Canada Surface Water Data were cross referenced to the same sampling station used by Ministry of Environment personnel for water quality data by station number. In this manner, any interpolation was minimized and only sampling, analytical, streamflow measurement and sampling time errors

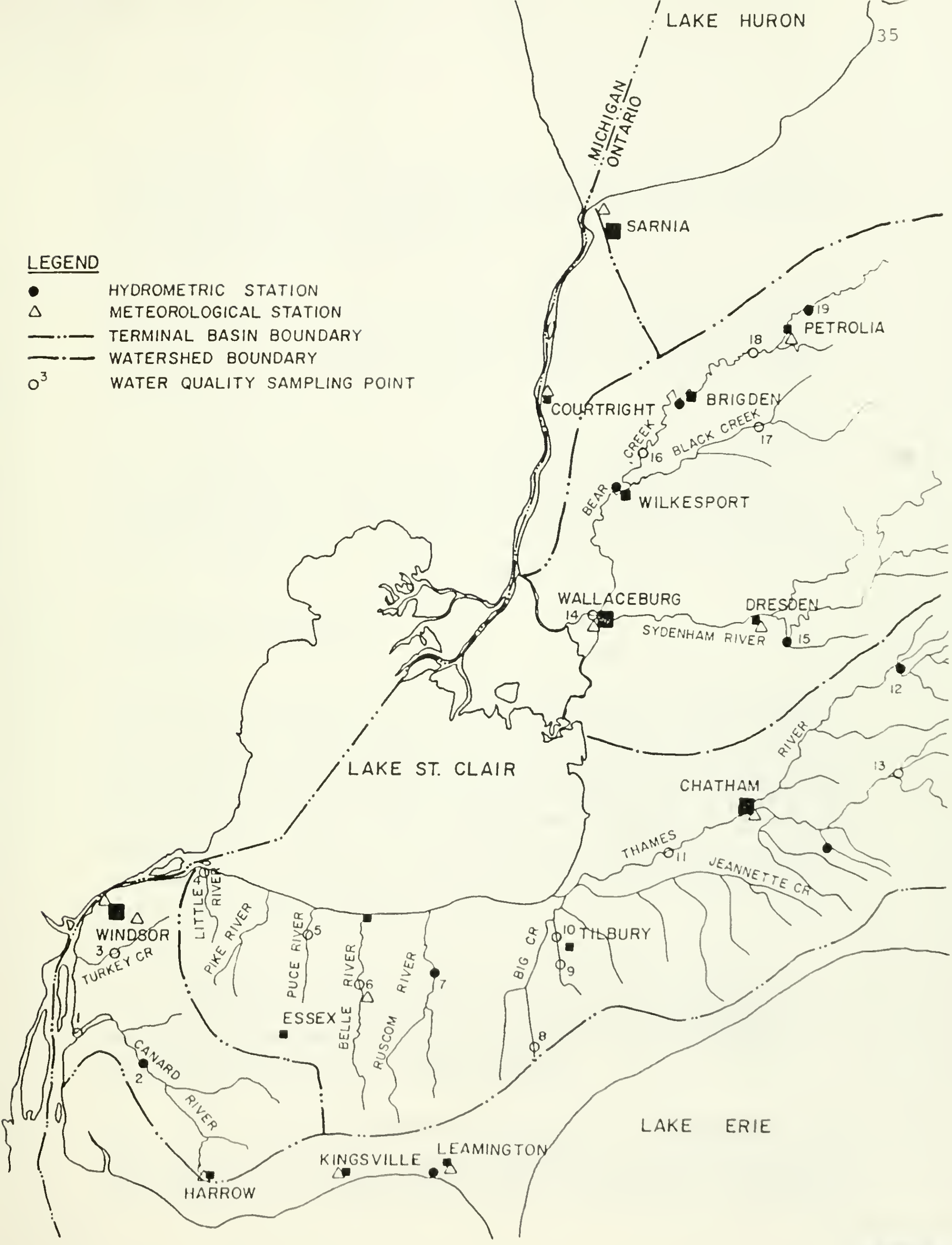


Figure 2.3.3 Network Monitoring Stations

affected the accuracy of the data. These errors were not quantified since the figures developed were for comparative and demonstrative purposes only.

The Thames River was not investigated at length since it has been the focus of several earlier Ministry of Environment studies (i.e., Thames River Basin, Water Management Study, Ministry of Environment, 1975).

The daily streamflow data were used to calculate suspended and dissolved solids transport in the Canard, Ruscom, Sydenham Rivers and Bear Creek. Streamflow data were also used to examine the concentration/discharge characteristics of the four streams in the study area.

Streamflow Discharge

Streamflow data available up to 1982 for the Thames River at Thamesville, Ruscom River at Ruscom Station, Canard River near Lukerville and Sydenham River were analyzed to determine the monthly mean flow distribution characteristics (maximum and minimum flows). These properties are useful in assessing the dilution capability and assimilative capacity of the receiving stream prior to discharge into the Detroit River, St. Clair River or Lake St. Clair.

The maximum and minimum monthly mean flow data were statistically analyzed to also determine the variation in monthly mean flows which was plotted to illustrate the differences across the cases examined.

The ratio of the maximum and minimum mean monthly flows was used as a measure of the basin response to rainfall and as an indication of its recharge/discharge properties. A "level"

monthly mean flow suggested greater bank storage and ground water recharge/discharge whereas a strongly bimodal distribution suggested greater run-off and less recharge/discharge.

These parameters along with actual flow figures were considered to also indicate the potential fluvial transport capabilities of the catchment basins drained by the rivers and streams. With discharge figures for the Detroit River, the impact from the above fluvial systems could be better assessed. The ground water component of streamflow is analyzed in greater detail in Section 2.3.2.3.

The result of the loadings calculations are illustrated in Figures 2.3.4 to 2.3.7.

Loading

For the Sydenham River, the suspended solids loading varied from a low of 31 g/s in September to a high of 10,771 g/s during April. The respective dissolved solids loading figures were 390 g/s in October to 23,990 g/s.

The Bear Creek had suspended solids loadings ranging from 1 g/s to 2225 g/s in April. The dissolved solids loadings ranged from 1 g/s in October to 4130 g/s during April.

The Ruscom River had suspended solids loadings of 1 g/s in February, 2.2 g/s in August and November to a high of 860 g/s during April. The dissolved levels varied from 22 g/s during August to 4327 g/s during April.

The Canard River had a low suspended solids level in February, August and November of 1 g/s and a high level of

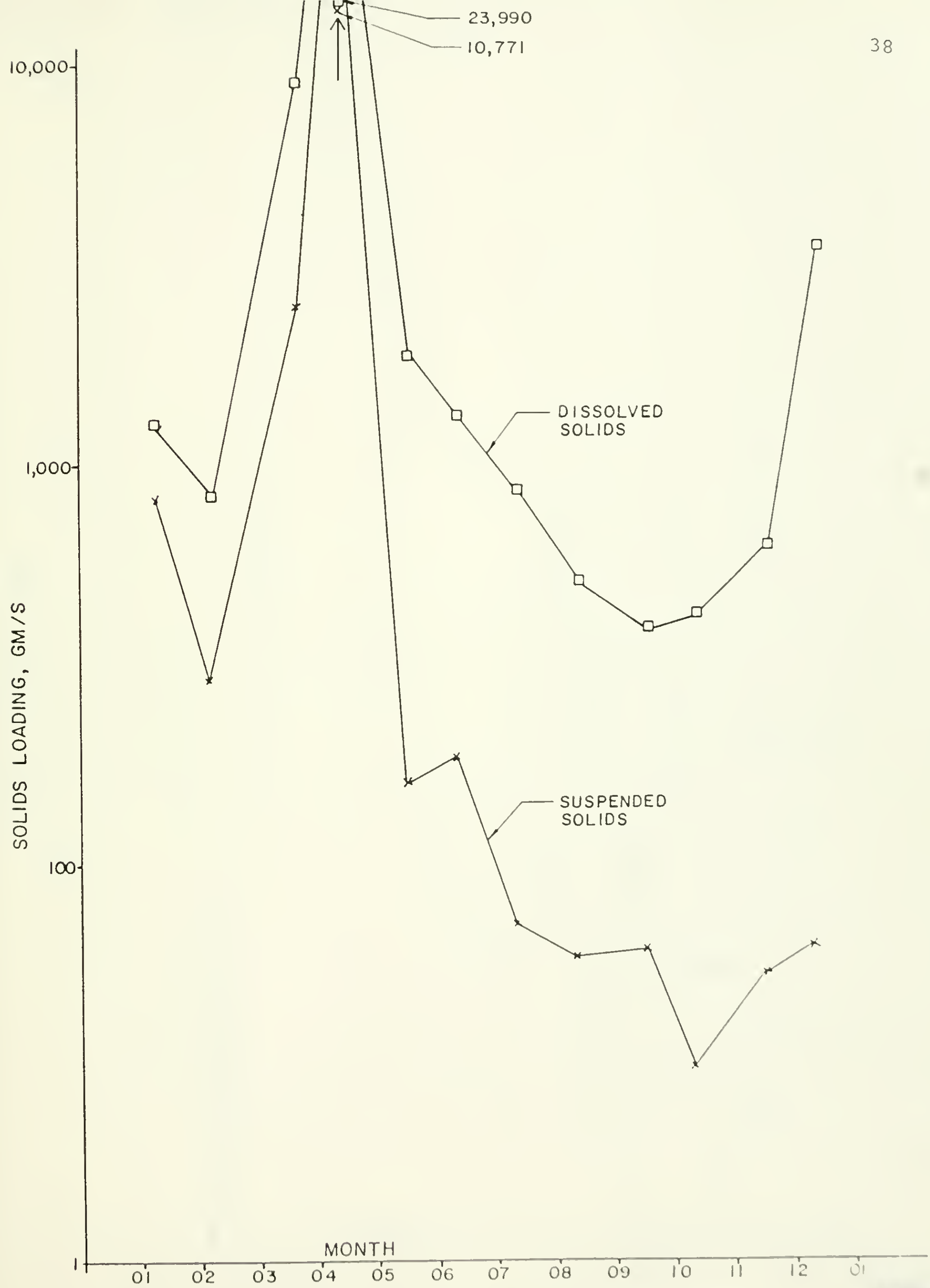


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Figure 2.3.4 Solids Loading, Sydenham River, 1979

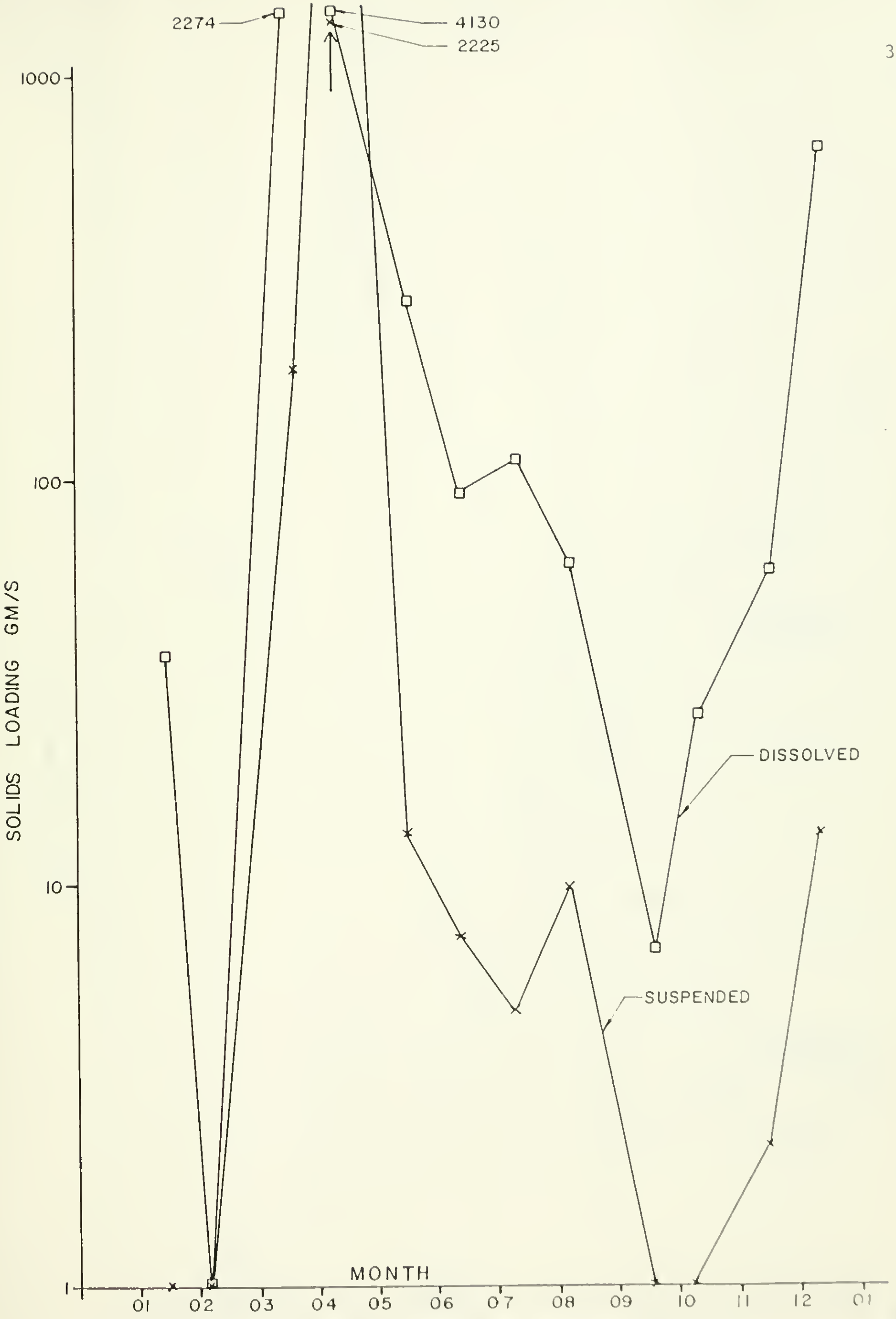


Figure 2.3.5 Solids Loading, Bear Creek, 1979

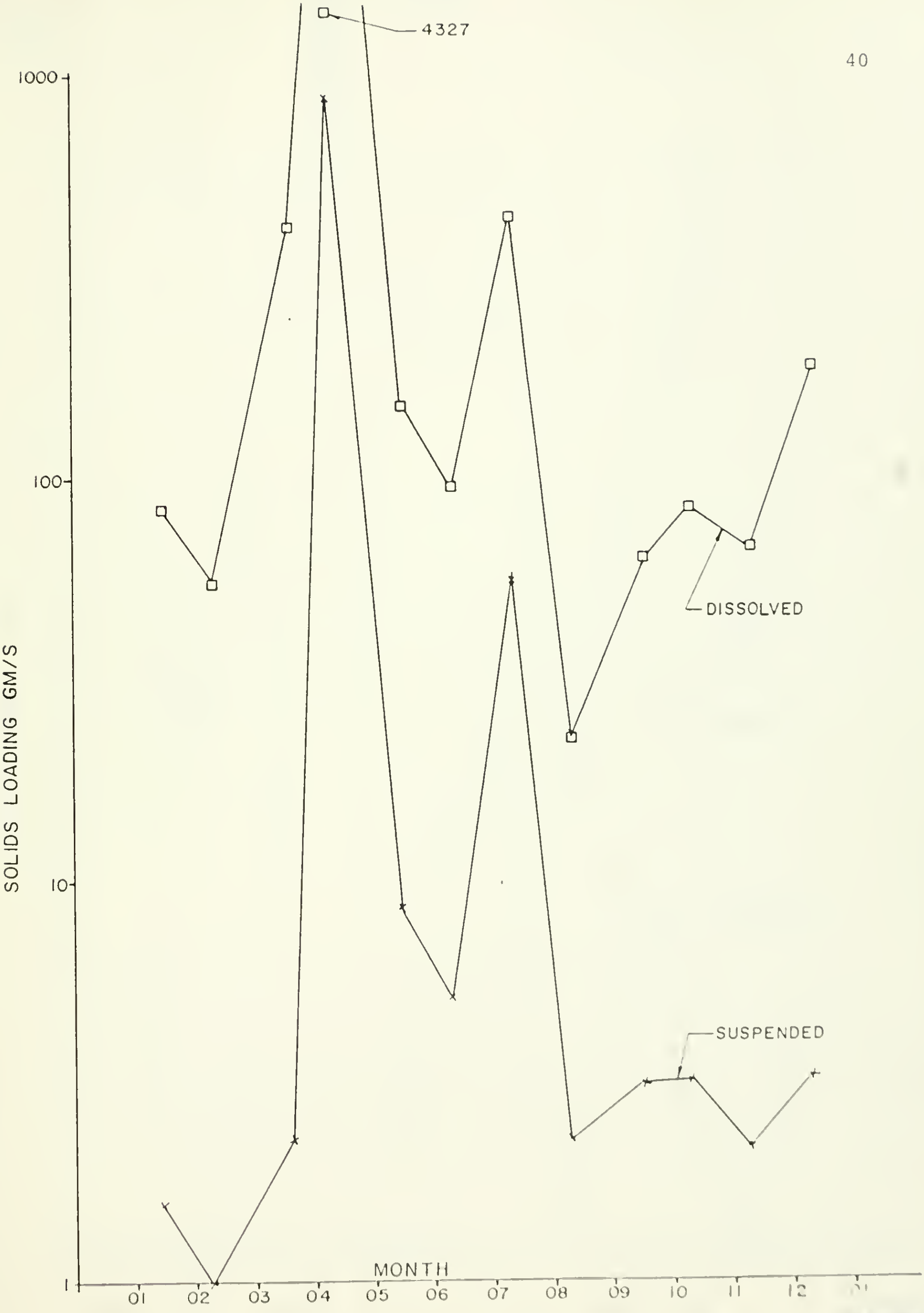


Figure 2.3.6 Solids Loading, Ruscom River, 1979

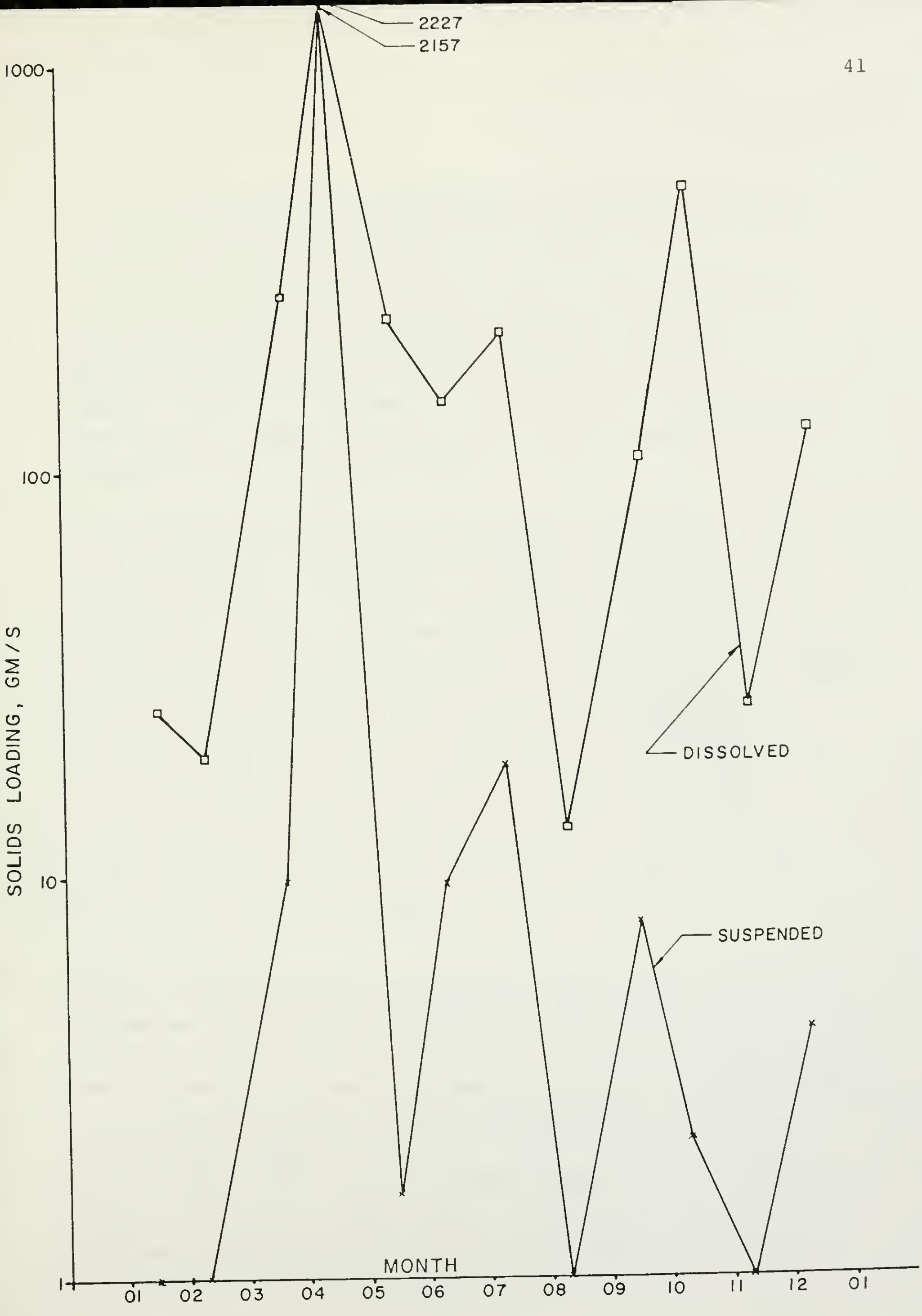


Figure 2.3.7 Solids Loading, Canard River, 1979

2157 g/s during July. The dissolved solids levels ranged from 13 g/s in August to 2227 g/s in April.

For the Thames River, the monthly mean flow varied from 12.9 m^3/s in August to 143 m^3/s in March. For the Sydenham River, the monthly mean flow was 2.3 m^3/s in August to 35.7 m^3/s in March. The ratio of the springtime peak flow to summer low flow was 11.3 for the Thames River and 15.5 for the Sydenham River.

The smaller river basins showed similar discharge characteristics. The Bear Creek had a mean maximum springtime flow of 8.13 m^3/s in March and a low flow of .313 m^3/s in August. The maximum/minimum ratio was 26, a much higher value than the larger watersheds. For the Canard River system, the monthly mean peak flow in March was 5.02 m^3/s and the mean maximum low flow in August was .17 m^3/s for a maximum/minimum ratio of 29.5. For the Ruscom River, the mean maximum peak flow of 3.61 m^3/s occurred in March as well and the low flow of .23 m^3/s occurred in August for a maximum/minimum ratio of 15.7.

2.3.2.3 Hydrograph Analysis

Annual and individual storm event runoff and precipitation values were examined from historical data for streams in the study area to provide information on run-off characteristics and catchment infiltration capacity. The streams were chosen on the basis of their close areal proximity to existing meteorologic sampling stations, simple basin geometry and uniform soil type. Small catchment areas were preferred because of their presumed linear response to rainfall events. Upstream catchments (lower order) were preferred because of the expected simpler relationship of their runoff response to

rainfall events and to the minimal absence of run-off from interbasins. The four catchments selected were within the Sydenham River, Bear Creek, Ruscom River and Canard River watersheds. The hydrometric and meteorological recording stations involved in the analysis are outlined in Figure 2.3.3 and Table 2.3.2.

The rainfall data were obtained on a daily basis thus preventing the generation of true hourly rainfall excess values. More accurate measurements of initial abstraction, actual retention and run-off values for storm events were not possible because of this shortcoming. In addition, no correction was made for the antecedent moisture conditions. However, efforts were made to allow for 5 days of no precipitation prior to the storm event studied. The direct run-off hydrographs included only runoff that began after a change in the baseflow was observed in the hydrometric data. Where possible, only singular, isolated storm events were chosen.

Spatial and temporal anomolies in the rainfall data were not identified except to compare the shape and duration of the hydrograph with the rainfall intensity duration data. For this reason, rainfall data for the Windsor Airport appeared to more closely represent input to the Canard River catchment area than corresponding data from the Harrow Station.

The annual rainfall and run-off volumes were calculated for each river catchment area (Table 2.3.3). The percentage runoff figures (annual run-off/(Basin size times annual precipitation)) were calculated to reflect the long term steady state discharge to surface water courses for each catchment area. It was assumed that the annual run-off

Table 2.3.2 Sampling Stations

River Basin	Hydrometric Station[1]	Meteorological Station[2]
Bear Creek	near Petrolia # 02GG006	Petrolia
Canard River	Near Lukerville #02GH003	Windsor Airport
Ruscom River	Ruscom Station #02Gh002	Woodslee
Sydenham River	Near Dresden #02GG007	Dresden

[1] Surface Water Data, Ontario, 1979, 1983 Inland Waters Directorate Water Survey of Canada.

[2] Canadian Climate Centre, Atmospheric Environment Service, Environment Canada.

Table 2.3.3 Hydrograph Results for Select Streams

River	Basin Size (km^2)	Major Soil Type	Year	Annual Precip. (mm)	Annual Runoff (x10^{7}m^3)	Runoff Ratio Annual (%)	Runoff Ratio Storm (%)	Time to Peak (days)	Catchment Infiltration Capacity (mm/HR)
Sydenham	1240	sand plain	1979	761.1	39.9	42.3	17.7	3.5	.448
Sydenham			1983	862.8	38.5	40.0	1.78	1.0	.210
Bear Creek	267	clay plain	1979	852.1	7.27	32.0	8.5	3.5	.198
Bear Creek			1983	919.0	6.3	25.7	3.1	6.4	.130
Ruscom River	125	clay plain	1979	907.6	3.06	27.0	1.38	1.4	2.05
Ruscom River			1983	1001.4	3.982	31.9*	2.69	1.0	2.05
Canard River	159	clay plain	1979	888.0	3.75	26.6	1.73	1.5	1.20
Canard River			1983	1066.3	6.19	36.6	36.1	3.0	8.56

* 11 months

Statistical Tests

(1) Annual vs individual storm runoff percentages
(.95,7) = 2.365
(calculated) = 3.73
95 % certainty that (2) has not occured by random chance.

(2) Sydenham River Catchment behaved differently than 3 other systems
(.95,5) = 2.57
(calculated) = 2.65
95% certainty that Sydenham catchment displays unique hydrologic response

$$1 = \frac{(\ -\ \%\ \text{Runoff})\ (\text{Excess Rainfall})}{\text{Time to Peak} \times 24}$$

ratio (annual run-off/(Basin size times annual precipitation)) represented both storm run-off and baseflow contributions to streamflow discharge. The storm events were analyzed by single event hydrographs to compute the direct run-off component. The initial rainfall excess (rainfall minus run-off) up to the Time to Peak (T_p) was considered to reflect the relative infiltration capacity of the catchment areas investigated.

The results of the basin storm run-off hydrograph analysis and annual rainfall/run-off ratio for the catchment areas are outlined in Table 2.3.3. Complete storm hydrographs are found in Appendix A.

The results suggest that for this region single storm events behave quite differently than the corresponding annual figures would indicate. The low percentage of run-off during single storm events suggests that recharge of the catchment area predominates and is followed by a longer slower discharge of the ground water through contributions to baseflow probably due to the low transmissivity of the clay soils. This observation suggests that the potential exists for contamination of ground water systems by the repeated flushing of surface contamination into the soil column and eventually the ground water.

The infiltration capacity figures (Table 2.3.3) show a 10 fold range in values from a high rate of 2.05 mm/hr for the Rascom River to a low value of 0.130 mm/hr for the Bear Creek watershed. These figures are an order of magnitude lower than typical values quoted for sandy loam soils (e.g., 20 - 5 mm/hr, Kohne and Bertrand, 1959).

Ranking of the catchment areas with regard to their potential to transport surface contamination into the ground water based on the infiltration capacity during storm events would place the Bear Creek and Sydenham River catchments lowest and the Ruscom River and Canard River basin at the top of the list.

2.3.3 Major Soil Groups

The major soil groups in the Southern section of the study area are shown in Figure 2.3.8. The properties of these soils groups are outlined in Table 2.3.4. Generally, this area is composed of dark grey gleysols with intermingled grey-brown podzols.

The dark grey gleysols are characterized by a high soil moisture content and poor aeration. The high water table restricts the downward movement of soluble minerals. Soils of this group showing discolorations of brown or grey have been exposed to fluctuating water table levels and show significant leaching.

The dark brown podzols develop under a deciduous or mixed forest vegetation. The formation of a textured B (B_t) horizon in this soil group is due primarily to the translocation of clay in suspension from an upper layer.

2.4 Hydrogeology

This section describes, for the study areas, the ground water flow systems and their hydrogeologic properties. A discussion of contaminant transport and attenuation mechanisms is found in Appendix 2.

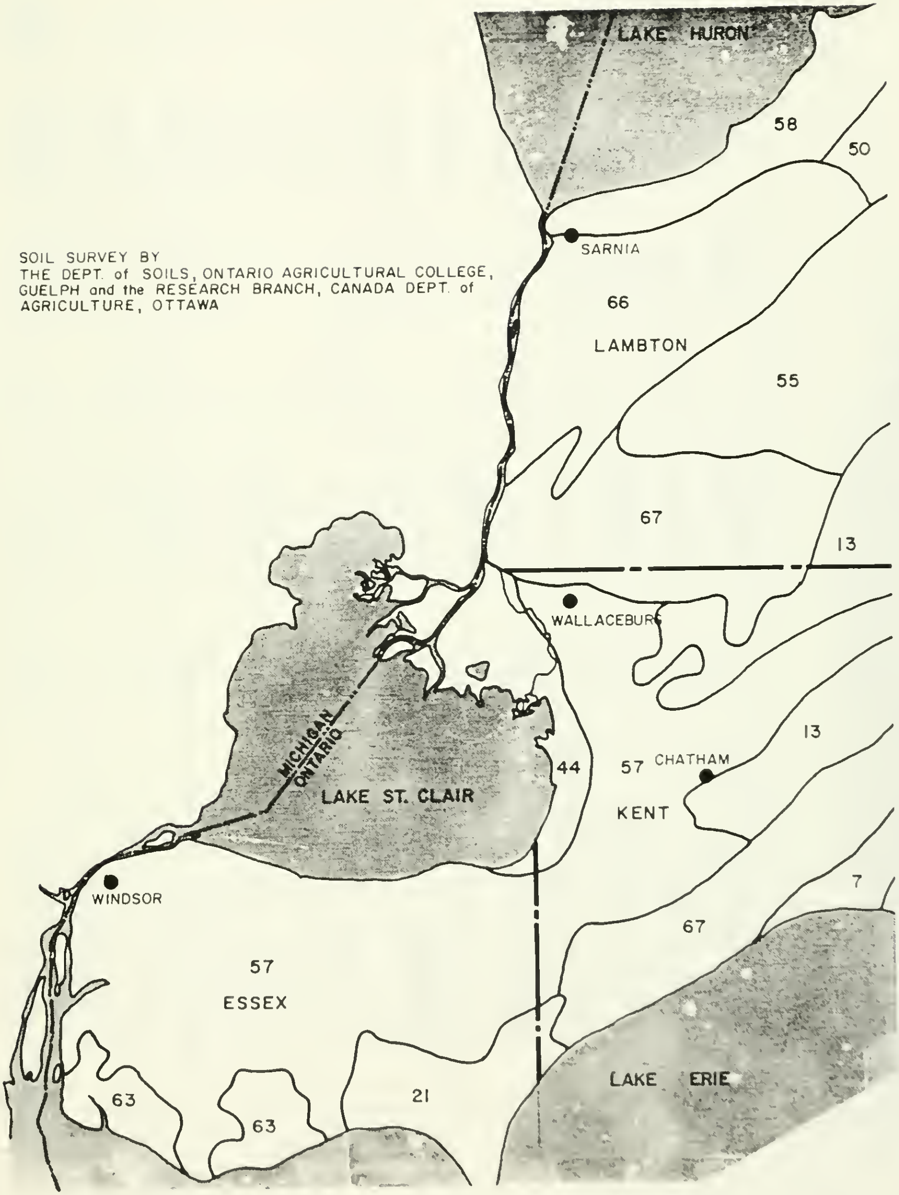


Figure 2.3.8 Major Soil Types for Sarnia-Windsor Area

INTERA

Table 2.3.4 Soil Associations of Study Area

Symbol	Great Soil Group(s)	Texture	Topography	Drainage	Surface Reaction	Surface Stoniness	Parental Material
7	grey-brown Podzol (Burford)	loam	undulating	good	slightly acid	few stones	A
13	grey-brown Podzol (Brady)	sandy loam	very gently undulating	imperfect	neutral	stonefree	A
21	grey-brown Podzol (Berrien)	sandy loam	undulating	imperfect	slightly acid	stonefree	B
44	dark grey Gleysolic	silt loam	very gently undulating	poor	neutral	stonefree	C
50	grey-brown Podzol (Perth)	clay loam	undulating	imperfect	neutral	stonefree	D
55	grey wooded (Renfrew)	clay loam	undulating	imperfect	medium acid	stonefree	D
57	dark grey Gleysolic (Brookston)	clay loam	very gently undulating	poor	neutral	stonefree	D
58	dark grey Gleysolic	clay loam	very gently undulating	poor	neutral	stonefree	D
	grey-brown Podzol	clay loam	undulating	imperfect	neutral	stonefree	D
63	grey-brown Podzol (Haldimand)	clay	undulating	imperfect	medium acid	stonefree	E
66	dark grey Gleysolic	clay	very gently undulating	poor	slightly acid	stonefree	E
	grey-brown Podzol	clay	undulating	imperfect	medium acid	stonefree	E
67	dark grey Gleysolic	clay	very gently undulating	poor	slightly acid	stonefree	E

Legend:

A: Dominantly coarse textured soils formed on sand and gravel.
B: Dominantly coarse textured soils overlying clay or clay loam till.
C: Dominantly moderately fine textured soils formed on very fine sands and silts.
D: Dominantly fine textured soils formed on till or lacustrine sediments.
E: Dominantly very fine textured soils formed on till or lacustrine sediments.

2.4.1 Ground Water Flow System: Sarnia-Windsor Area

The local scale ground water flow system in the Sarnia-Windsor area is controlled primarily by surface infiltration with shallow discharge to ditches, creeks and rivers. The intermediate scale flow systems are generally associated with thick unweathered clay and till sequences and are likely characterized by slow downward movement. The regional scale ground water flow systems are those contained in, or associated with, the bedrock. In this report the regional flow systems will be limited to the thin sand and gravel aquifer at the top of the bedrock and the fractured upper surface of the bedrock. Deeper regional aquifers are likely contained in the bedrock (e.g., Detroit River Group) but will be only briefly addressed.

The conceptual ground water flow systems in the Sarnia-Windsor area are shown schematically in Figure 2.4.1.

2.4.1.1 The Local Scale Ground Water Flow System

The local scale ground water flow system consists of the water table and associated flow in the shallow subsurface. It is contained in the surficial sand and gravels (e.g., sand plains and moraines) and the weathered and fractured zone of the lake clays and clay tills. Flow in this system would be strongly influenced by precipitation events and result in either discharge to shallow ditches, creeks and rivers or recharge to the deeper clay and till zones.

The weathered zones of the clay plains have developed as a result of surface oxidation and leaching causing compositional changes in the clay. Leaching of carbonate from the shallow surface and a corresponding decrease in

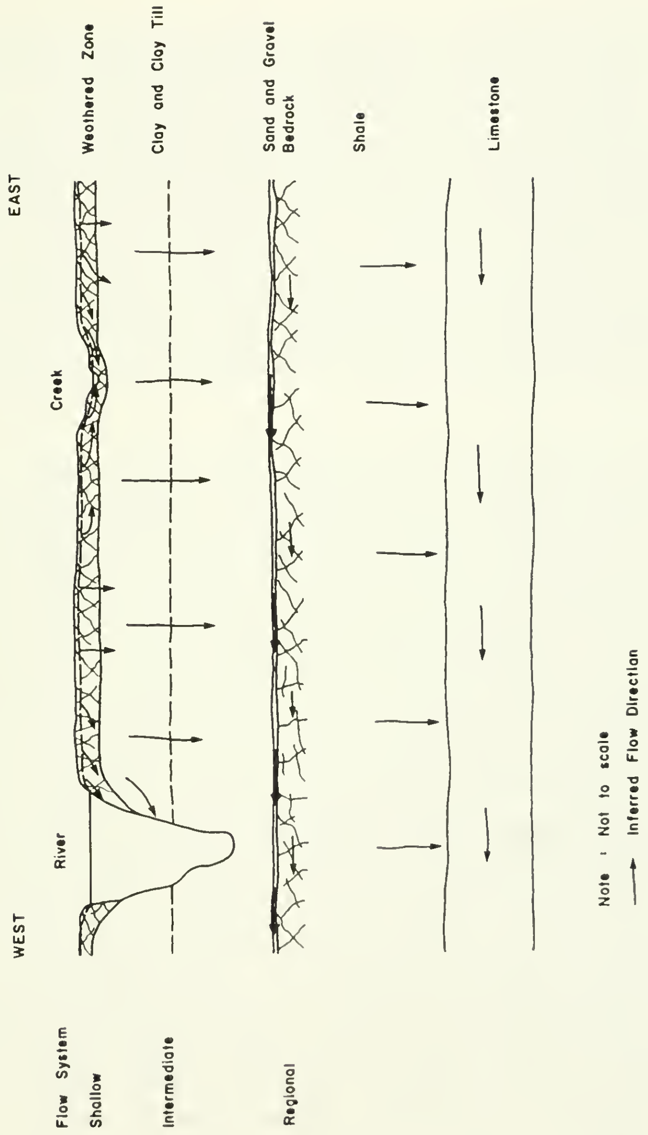


Figure 2.4.1 Schematic Cross Section Illustrating the Ground Water Flow Systems

moisture content has been noted by Quigley and Ogunbadejo (1976) and suggests that carbonate deposition and desiccation play important roles in the weathering process. Leaching and desiccation have resulted in closely spaced fissures in the near surface which increase to spacings of about 1.0 m at depths of 5 m (Quigley and Oqunbadejo, 1976). Associated with the fissures are precipitations of iron hydroxides and gypsum. Oxidation of the clay causes a marked discoloration in the vicinity of the fissure. Rootlets which follow the fissures have been noted to depths of 9 m.

It is difficult to determine the exact cause or causes of fracture patterns in glacial tills and very little information in the literature is available for the Sarnia-Windsor area. Natural fracture patterns usually depict the local state of stress at the time of fracturing. Fractures in clay tills may have formed by: (1) regional extension of the earth's crust due to crustal rebound following glacial loading; (2) a primarily vertical stress imposition and release in the Quaternary deposits following the readvance of glaciers; or (3) volume changes due to dessication during altithermal conditions during glaciation. Volume changes may be a result of subaerial drying (dessication), syneresis (bulk volume reduction by dewatering of constituent clay material) or mineral phase-changes (i.e., calcite phase change to dolomite or montmorillonite to illite causes a volume change). Most surface fractures (upper few metres) found in clays can be attributed to desiccation and freeze-thaw processes. These mechanisms, as described by Grisak et al. (1976), are essentially the same as those described by Nelson (1979).

Vonhof (1970) has suggested that vertical fractures at several till locations in Saskatchewan formed either: "(a) as fractures between horizontal to near-horizontal shear joints or (b) during loading or unloading of underlying till by advancing or receding continental ice sheets". Similar mechanisms may be at work in the Sarnia-Windsor area. At locations where bedrock fractures correspond to till fractures crustal rebound following glaciation is a probable mechanism. Regional bending of bedrock may also be a factor in fracture formation.

The thickness of the weathered zone is typically less than 6 m but Hanna (1966) reported that fractures may extend to depths of 10 m from surface. The fissures between 1.5 and 3.0 m depth have been noted by Quigley and Oqunbadejo (1976) to be in two sets which dip nearly vertically and strike at almost right angles to each other.

Because of the fractured and weathered nature of the shallow clays this local system is likely to be more active than the deeper intact clays (intermediate zone). The presence of fractures in the weathered zone represent an increased permeability and relatively open conduits for the transmission of water. Movement of ground water and contaminants, if present, would be more rapid through the fissure networks than through similar unweathered clays.

The direction of ground water flow in the local system will be dependent on the specifics of the location but, in general, it is expected that this system will have both a horizontal and vertical component of flow. The horizontal component will be the result of increased permeability of the weathered zone over the intact clay causing increased lateral ground water flow. In the shallow system, ground

water will flow primarily towards the surface water bodies (i.e., rivers, creeks, drainage ditches). A small component of the flow system will be directed downward to recharge the deeper systems.

2.4.1.2 The Intermediate Scale Ground Water Flow System

The intermediate scale ground water flow system, in this study, is taken to include the thick sequences of intact lacustrine clay and clay till that overlie the sand and gravel aquifer at the bedrock contact. The thickness varies but is typically less that 40 m. The clay and till units are essentially massive, although they may contain thin discontinuous silt and sand layers particularly between the upper St. Joseph Till and the lower Black Shale Till (Section 2.2.1.1).

Ground water flow in this system is likely downward, toward the aquifer at the bedrock contact, at a very slow rate although locally there may be discharge to relatively deep rivers (e.g., St. Clair River). Significant vertical gradients exist across these units but with hydraulic conductivities typically on the order of 10^{-10} m/s (see Section 2.4.2) migration by hydraulic flow can be expected to be very slow. With such low flows the most dominant contaminant transport mechanism will be by diffusion.

The transit times estimated for ground water movement through the clay sequences to bedrock at the Tricil Site in Moore Township are in the range of 14,800 years to in excess of 1.7 million years for simple hydraulic flow, and in the range of 2000 years for contaminant migration due to diffusion (Hydrology Consultants, 1984). Contaminant flow and transport in low permeability stratigraphic units is described in more detail in a later section.

2.4.1.3 The Regional Scale Ground Water Flow System

The regional scale ground water flow systems in the Sarnia-Windsor area are contained in the bedrock units. Of primary importance to this study is the "fresh water" aquifer located at the overburden-bedrock contact. Deeper regional flow systems are likely found throughout the sedimentary sequences illustrated in Figure 2.1.1.

The fresh water aquifer is a poorly sorted sand and gravel unit located at the top of the bedrock. This unit is often described as a basal till. It is thin, usually less than 3.0 metres, and is often discontinuous. Rock fragments comprising the aquifer reflect the composition of the adjacent bedrock.

The aquifer is confined by the overlying clay units and represents one of the major water supply aquifers in the area. Locally the yield is limited, with typical yields ranging from 0 - 7.5 x 10^{-4} m^3/s (0 - 10 gpm). Low yields are likely due to the aquifer's discontinuous nature and limited transmissivity. Wells located in this aquifer are usually drilled and cased into the bedrock. The well intake is contained in the bedrock and draws on the fracture networks in the shallow rock to yield water from the bedrock as well as the sand and gravel unit at the contact. Although the wells are screened in the bedrock the ground water is considered indicative, from a water quality standpoint, of the sand and gravel aquifer.

The ground water flow directions in the fresh water aquifer have been evaluated using MOE water well records for Lambton, Essex and Kent countries. The well record interpretations must be used with care due to the uncertainties associated

with the original data. The static water levels of these wells are usually measured immediately after drilling and well development and, therefore, may not have reached equilibrium when reported.

Another difficulty in evaluating the data is due to the period of reporting. The data span over forty years and readings were taken at different times of the year. The well elevations used to determine the piezometric elevations were not surveyed, but, are in fact an estimate taken from topographic maps. Errors of approximately ± four meters are therefore possible. As a result, the ground water flow directions derived from the data should not be taken as absolute. They do serve, however, to indicate the approximate flow directions which may be encountered under a controlled field study.

The criterion used to obtain a representative sample of piezometric levels for presentation was to obtain at least one data point per four square kilometers of study area unless a significant variation in the parameter of interest was observed. In such a case a higher density of data points (well logs) was utilized. Unfortunately, some areas exist where data is sparse and the selection criteria could not be met.

The regional flow directions for the Sarnia-Windsor area are shown in Maps 071-6-E, 071-6-K, and 071-6-L. Bearing in mind the uncertainties described above, regional flow directions can be estimated for the fresh water aquifer. In general the regional trend is towards the large surface water bodies in the area. In Lambton County, as is shown in Map 071-6-L, the flow is primarily to the west and northwest towards the St. Clair River and towards the southern end of Lake Huron.

In places along the St. Clair River, the hydraulic head is near or slightly above river level. This will result in discharge from the aquifer to the river. Locally, however, the gradient may be reversed and the fresh water aquifer may be recharged by the river.

This situation likely occurs south of Sarnia, where the hydraulic head is approximately equal to or less than the river level elevation. If the head in the fresh water aquifer was artificially increased, such as by deep well injection, the potential for discharge of the fresh water aquifer to the river will increase.

Similarly the flow directions in the fresh water aquifer for Kent County are predominantly westerly and southerly towards Lake St. Clair and Lake Erie respectively. Water level elevations are significantly below the level of Lake St. Clair but levels near Lake Erie indicate that discharge to the lake may occur. In Essex County, the flow directions extend radially from a potentiometric high in the south center of the county and flow in the fresh water aquifer is directed towards the northwest, west, and south. In the southern part of the county, discharge from this aquifer to Lake Erie likely occurs.

Recharge to the fresh water aquifer likely occurs primarily through the surficial sand and gravel deposits located to the east of the study area (i.e., outside of the St. Clair Clay Plains). A small recharge contribution is likely obtained also from the overlying clay units by downward hydraulic movement.

As well as the fresh water aquifer, there are several deeper ground water flow systems that could be included in the regional flow system. One of these, important to this study, is that contained in the Detroit River Formation which is a permeable dolomitic and cherty limestone unit. This unit has been used for waste disposal by deep injection wells and has been studied by Vandenberg et al. (1977). Ground water flow directions in this aquifer are predominantly westward and hydraulic heads for this aquifer in its undisturbed state are typically 75 - 100 metres below surface. This aquifer is confined by the overlying shales and shaley limestones of the Kettle Point and Hamilton Formations. Aquifers such as this and others located deeper in the geologic section are not used as domestic water supplies in this area.

2.4.2 Hydrogeologic Properties

The hydrogeologic properties of the soils, surficial deposits and fresh water aquifer in the Sarnia-Windsor area have been investigated in a number of studies. Typical values of hydraulic conductivity, porosity and hydraulic gradient for a number of locations are given in Table 2.4.1. It is important to note the ground water system or type of material of which each value is representative because of their dramatically different properties (i.e., the intermediate scale represented by intact till could have a hydraulic conductivity several orders of magnitude lower than the sand and gravel aquifer of the regional scale system).

2.4.2.1 Hydraulic Conductivity

Hydraulic conductivities for the three ground water systems have been determined by three test methods: slug tests; permeameter measurements; and pumping tests. The slug test,

Table 2.4.1 Typical Hydrogeologic Properties for the Sarnia-Windsor area

Source	Location	Type of Material	Hydraulic Conductivity (m/s)		Porosity	Hydraulic Gradient	
			Field	Lab		vertical*	horizontal
Desaulnier et al., 1981	Sarnia	Fractured and intact till	$1.4\text{x}10^{-10}$	$2.8\text{x}10^{-10}$	0.29-0.41	-0.02-0.17	
	Wyoming	Fractured and intact till	$0.92\text{x}10^{-10}$	$2.7\text{x}10^{-10}$	0.22-0.38	-0.02-0.42	
	Woodslee	Fractured and intact till	$1.2\text{x}10^{-10}$	$2.9\text{x}10^{-10}$	0.31-0.37	+0.03-0.21	
Desaulnier, 1982	Lambton G.S.	Fractured and intact till	$0.32\text{-}11.5\text{x}10^{-10}$	$0.54\text{-}14.8\text{x}10^{-10}$	0.43	-0.03-1.27	
Conestoga-Rovers Assoc., 1980	Petrolia		$8\text{x}10^{-11}$	$7\text{x}10^{-10}$			
Golder Assoc., 1981	Amherst-berg	Fractured till	$1.0\text{x}10^{-10}\text{-}1.4\text{x}10^{-6}$	$1.8\text{x}10^{-9}$		-0.03-0.8	0.004-0.07
		Sand & gravel	$10^{-7}\text{-}10^{-6}$				0.001
Hydrology Consultants, 1984	Tricil	Fractured till	$1.5\text{x}10^{-10}\text{-}2.85\text{x}10^{-7}$				0.001-0.02
		Intact till	$1\text{x}10^{-11}\text{-}1\text{x}10^{-10}$	$2.7\text{x}4.7\text{x}10^{-11}$	0.4	-0.028-0.21	
		Sand & gravel	$5.9\text{x}10^{-10}\text{-}2.7\text{x}10^{-7}$ $4.6\text{x}10^{-7}$ (3)				0.0045-0.19
Gartner Lee Associates Ltd. 1981	Ridge Landfill	Fractured till	$9.9\text{x}10^{-8}$		$0.01^{(1)}$		
		Intact till	$9.9\text{x}10^{-11}\text{-}9.9\text{x}10^{-10}$		0.35	-0.7	

Table 2.4.1 Typical Hydrogeologic Properties for the Sarnia-Windsor area (cont'd)

Source	Location	Type of Material	Hydraulic Conductivity (m/s)		Porosity	Hydraulic Gradient	
			Field	Lab		vertical*	horizontal
		Sand & gravel	$9.9x10^{-6}$		$0.01^{(2)}$		$6.5x10^{-4}$
O.H. Material Co., 1984	Welland Chemical	Fractured and Intact till	$3x10^{-9}$				0.01-0.02
MacLaren, 1982	Shell, Corunna	Fractured and Intact till	$4.8x10^{-10}-6.5x10^{-8}$	$2.4-7x10^{-10}$	0.1	-1.0	0.004-0.01
Dominion Soils, 1983	Dow, LaSalle Road	Fractured till	$2.7x10^{-9}-2x10^{-8}$				0.0025
		Intact till	$1.1-1.4x10^{-9}-2x10^{-8}$				
Dominion Soils, 1984	Polysar, Scott Rd.	Fractured till	$1.3-3.2x10^{-9}$				
		Intact till	$2.8-8.4x10^{-10}$			-0.032-0.66	0.013
Dominion Soils, 1983	Suncor	Fractured and Intact till	$7x10^{-8}-7.7x10^{-7}$				0.01
Corbin Drilling, 1983	Fighting Island		$3-4.3x10^{-9}$	$3-4.3x10^{-9}$			

Notes: All field values are from slug test except where noted

(1) Fracture porosity

(2) Effective porosity

(3) Pump test

* Note: For vertical hydraulic gradients (-) indicates a downward gradient

a field method, measures the rate of water level recovery after a "slug" of water has been added or removed from a piezometer. Because of low clay permeabilities in the study area, the water level in a slug test may take in excess of three months to fully recover.

Permeameter tests, a laboratory method, typically use a Shelby sample tube as the test vessel and in this manner the hydraulic conductivity is measured on a relatively undisturbed soil sample. This method gives values indicative of the vertical hydraulic conductivity because the falling or constant head would be applied over the length of the soil column. Permeameter tests are commonly performed on the weathered and intact clays. Other laboratory methods such as grain size analysis, used to determine hydraulic conductivity based on mean particle diameters have not been reported in Table 2.4.1 but are reported in the literature. It was judged that these methods were designed for sand and silt size particles and were not applicable to clays and clay tills.

Pump tests have been occasionally reported for the fresh water aquifer only. This fact is due to its moderate transmissivity as compared to the clay tills. However, with yields of less than 7.5 x 10^{-4} m^3/s (10 gpm), it is difficult to effectively stress adjacent piezometers. Consequently, pump tests are not routinely reported in the literature. Hydraulic conductivities can also be estimated based on well yields given in MOE water well records.

Hydraulic conductivities given in Table 2.4.1 for the local ground water system range from about 10^{-11} to 10^{-6}m/s with a mean of about 10^{-9} m/s. This wide range of values represents the weathered and fractured

nature, as well as the geologic variability, of the local systems. Weathering has broken down the structure of the original intact clays to reduce their permeability while fracturing, however produced, causes open conduits within the clay. Silt or sand seams within the local system may also contribute to the wide range of hydraulic conductivities even though the seams may not be extensive or continuous.

Hydraulic conductivities for the intermediate zone are in the range of 10^{-11} to 10^{-8} m/s with a qualitative mean of about 10^{-10} m/s. The low hydraulic conductivity stems from the dense compact nature of the intact clays and the inherent clay structure. This system is obviously of lower permeability than the overlying local system.

The fresh water aquifer, which is the most important regional system, has a much higher hydraulic conductivity in the range of 10^{-10} to 10^{-6} m/s with a mean of about 10^{-7} m/s. As mentioned, yields in this aquifer are typically less than 7.5×10^{-4} m^3/s (10 gpm). If the aquifer is assumed to be about 1.5 to 3.0 metres thick then aquifer transmissivities in the range of 1.5×10^{-10} to 3×10^{-6} m^2/s are likely, making it a poor aquifer for domestic water supply.

2.4.2.2 Porosity

Porosity values typical of the ground water flow systems in the Sarnia-Windsor area are given in Table 2.4.1. In the local flow system a dual porosity exists, in that both matrix and fracture porosities are present. Matrix porosities represent the actual pore spaces in the intact clays. A range of porosity values for the clay matrix of the local and intermediate system is about 22 to 43 per cent. By

comparison porosities due solely to the fracture networks in the local system are much lower and likely in the range of 0.4 to 1 per cent. These low values are due to low fracture frequencies in the clay tills and therefore the "open" space of the fracture aperture is small, compared to the "closed" volume of the matrix. The local system contains both fracture and matrix porosities and must be considered as a dual porosity system when considering ground water velocities and contaminant transport.

Porosity values for the fresh water aquifer have not been reported in the literature reviewed. Estimated values for the poorly sorted sand and gravel aquifer are likely in the range of 15 to 30 per cent. If the fractured bedrock is considered part of the fresh water aquifer then a fractured porosity and a dual porosity system must be considered. Porosities of fractured shale are typically less than 1 per cent.

2.4.2.3 Hydraulic Gradients

Hydraulic gradients representative of the three ground water flow systems are given in Table 2.4.1. In this study an attempt has been made to distinguish between vertical and horizontal gradients because of their significance and difference in terms of ground water velocities and contaminant transport. Horizontal gradients are most important in the local and regional systems, while the intermediate system has predominantly vertical gradients.

Horizontal gradients in the local system range from about 0.001 to 0.07 m/m. Gradients in the range of 0.00065 to 0.019 m/m exist for the fresh water aquifer. Vertical gradients for the intermediate system, and likely for a small

component of the local system, are considerably higher (in the range of 0.02 to 1.0 m/m). The difference in horizontal versus vertical hydraulic gradient is significant in terms of any potential contaminant migration. Low gradients are found in the more permeable units while the high gradients are predominantly vertical through the low permeability clay units. The highest potential for off-site contaminant migration exists in the weathered and fractured clay zone near the surface. Moderate gradients and moderate hydraulic conductivities in the local system will result in flow towards the local discharge points. In the intermediate system, high gradients are offset by low hydraulic conductivities and downward migration is very slow. In contrast, moderate gradients in the fresh water aquifer combined with the relatively high permeability will result in high ground water velocities.

2.4.2.4 Ground Water Velocities

The average ground water velocities for the ground water systems can be calculated using a modified version of Darcy's law:

$$v = -\frac{K}{n}\frac{dh}{dl}$$

where v = average ground water velocity,
K = hydraulic conductivity,
n = porosity, and
$\frac{dh}{dl}$ = hydraulic gradient (change in hydraulic head over a given distance).

In this manner, the hydrogeologic properties given in Table 2.4.1 can be used to estimate the ground water velocities due solely to hydraulic flow.

For the local system which has a dual porosity (matrix and fracture porosities) a wide range of velocities will result. For simple horizontal hydraulic flow in the matrix assuming average values of $K = 10^{-9}$ m/s, $dh/dl = 0.005$ and $n = 0.30$, the average ground water velocity will be about 1.7×10^{-11} m/s or 0.05 cm/yr. Obviously a wide range of velocities can be developed using the given ranges of each of the parameters. If a porosity typical of the fractures (i.e., $n = 0.01$) is used then the velocity will be dramatically different; about 5×10^{-10} m/s or 1.6 cm/yr. This estimate however ignores the matrix porosity and is not strictly valid. It is recognized that the fractures may be open and therefore ground water velocities could be quite high. If higher hydraulic conductivities are used with either a matrix or fracture porosity then substantially higher velocities can be predicted for the local system.

In the intermediate flow system the ground water velocity can be estimated using representative values such as $K = 10^{-10}$ m/s, $dh/dl = 0.1$ and $n = 0.30$ to yield a velocity of about 3.3×10^{-11} or 0.1 cm/year. This value is a vertical velocity and is similar to that given by Crooks and Quigley (1984) and Desaulnier et al. (1981). This ground water velocity is extremely slow and it is likely that the velocity of contaminants due to diffusion would be higher.

In the fresh water aquifer representative parameters such as $K = 10^{-7}$ m/s, $dh/dl = 0.005$ and $n = 0.20$ yield an average ground water velocity of 3×10^{-9} m/s or 8 cm/yr. This velocity is horizontal and is slow for a sand and gravel aquifer. If the fractured surface of the bedrock is considered using a porosity of about 0.01 the velocity is dramatically increased to 5×10^{-8} m/s or 1.6 m/yr.

2.4.3 Algoma District - Hydrogeology

The hydrogeology of the Algoma District - Sault Ste. Marie area can best be described in terms of the area geology. The crystalline basement rocks which form an upland area to the north of the St. Mary's River can be considered to be of relatively low permeability. This rock type will not transmit large quantities of water except possibly in association with faults and fractures. The sandstone which rests unconformably on the crystalline basement is considered to be the most extensive aquifer in the area. The reliability of this aquifer as a water supply however is largely determined by its fracture network and its connectivity to the overlying sand and gravel. It has been noted by International Water Consultants (IWC, 1978) that the transmissivity of this aquifer ranges between 1×10^{-3} to 1×10^{-2} m^2/s. Highly transmissive zones are likely be found near the bedrock surface and are probably associated with increased fracturing or connectivity to the sand and gravel overburden. Storativities for this aquifer are about 1×10^{-4} (IWC, 1978). This aquifer is, for the most part, confined by the overlying clay layers and many wells in the aquifer flow at surface. Flow directions in the sandstone aquifer are not defined but are likely to be towards the south, away from the basement uplands and toward the St. Mary's River. Locally, the flow directions may be influenced by the bedrock highs.

The sand and gravel unit found adjacent to the basement uplands likely acts as the recharge zone for the sandstone aquifer. The sand and gravel aquifer is unconfined in the north but may be confined locally if it extends southward under the clay sequences. It has hydraulic conductivities in the range of 1×10^{-5} to 1×10^{-3} m/s and storativities of 10^{-4} to 10^{-3} for areas where it is confined and

10^{-2} to 0.2 for areas where it is unconfined (IWC, 1978 and Gartner-Lee Associates Ltd., 1983). Hydraulic gradients in this aquifer are strongly downward (IWC, 1978) in the north indicating an area of ground water recharge and are likely to be near horizontal as the sand and gravel aquifer extends southward. Locally the sand and gravel will discharge to rivers and streams.

The clay sequences have not been suitably tested due to their low well yields and few wells are located in the clay tills. It is estimated that hydraulic gradients will be predominantly downward towards the sandstone bedrock and the hydraulic conductivity is likely of the order of 10^{-2} m/s (Gartner Lee Associates, 1983).

2.5 Surface Water Quality

Available surface water quality data (MOE, 1980; MOE, 1981a; MOE, 1981b) was examined and summarized. The sampling stations are shown on Figure 2.5.1. The summarized data for selected parameters are depicted on Figures 2.5.1 to 2.5.12.

The water quality revealed in general that stream water quality is closely linked with population density and agricultural activity. Throughout the study area, water quality is moderate to poor as a result of large population density and heavy farming. Point source contributions due to discharge of sewage treatment plant effluents are significant resulting in poor water quality in several cases.

Detailed surface water quality analysis surrounding disposal sites was non-existent or inadequate in all cases examined and therefore detailed discussions are not possible.

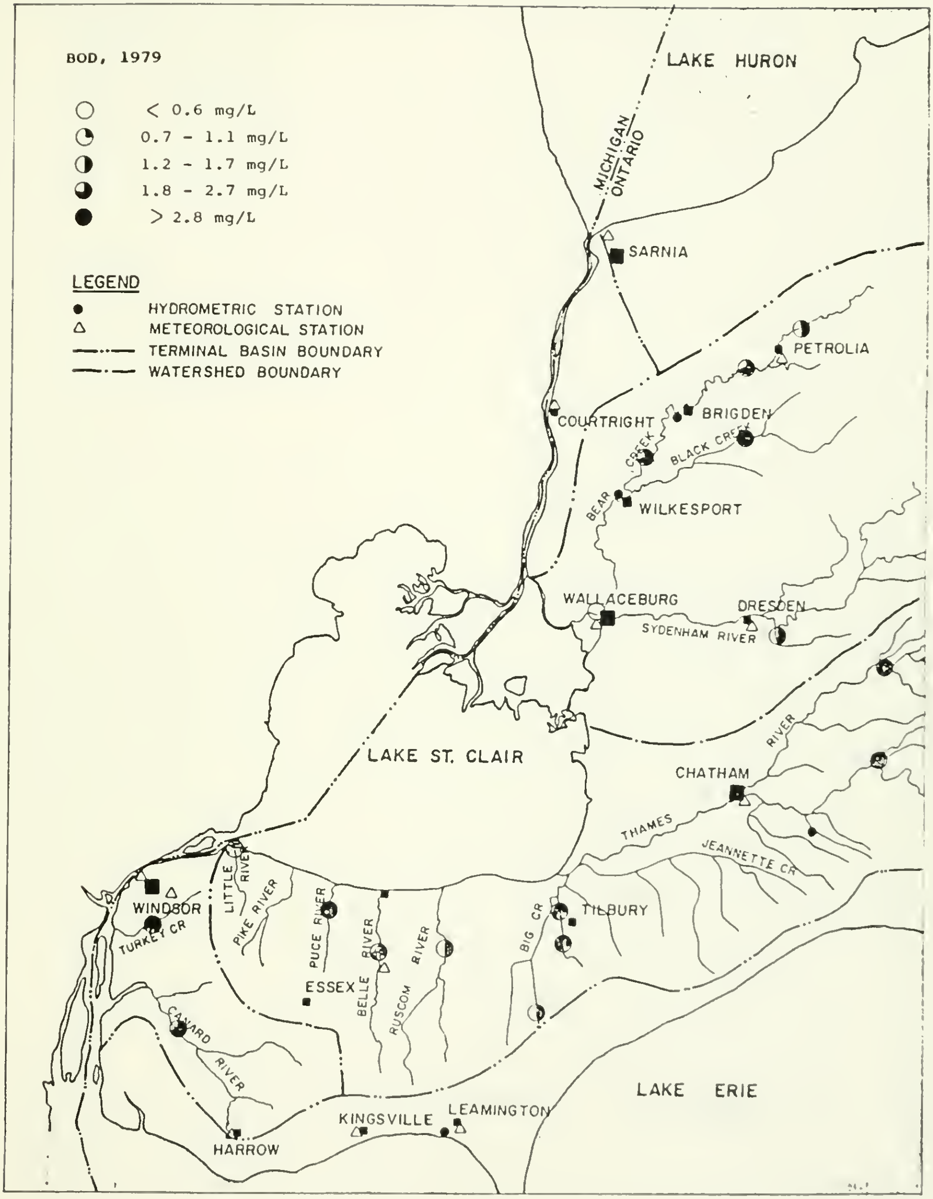


Figure 2.5.1 1979 BOD Data Summary

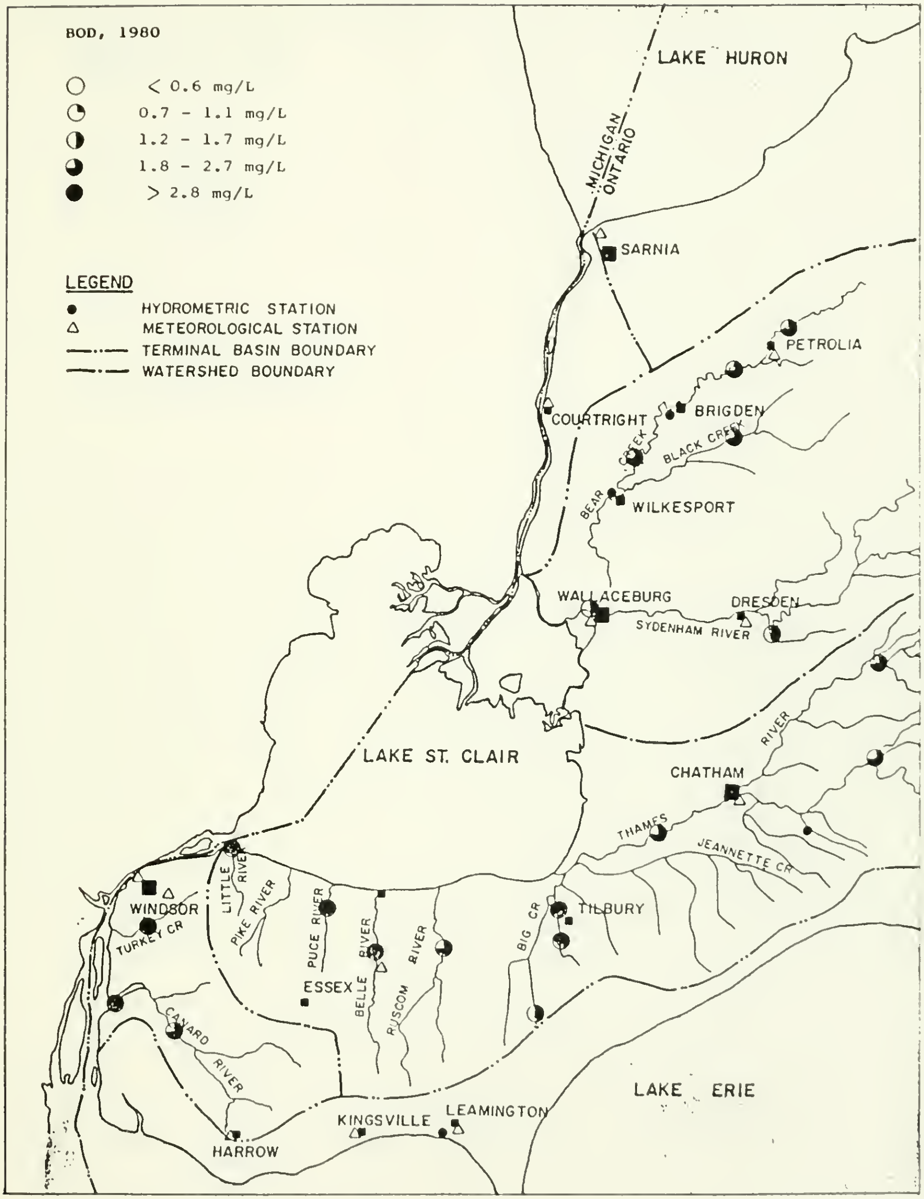


Figure 2.5.2 1980 BOD Data Summary

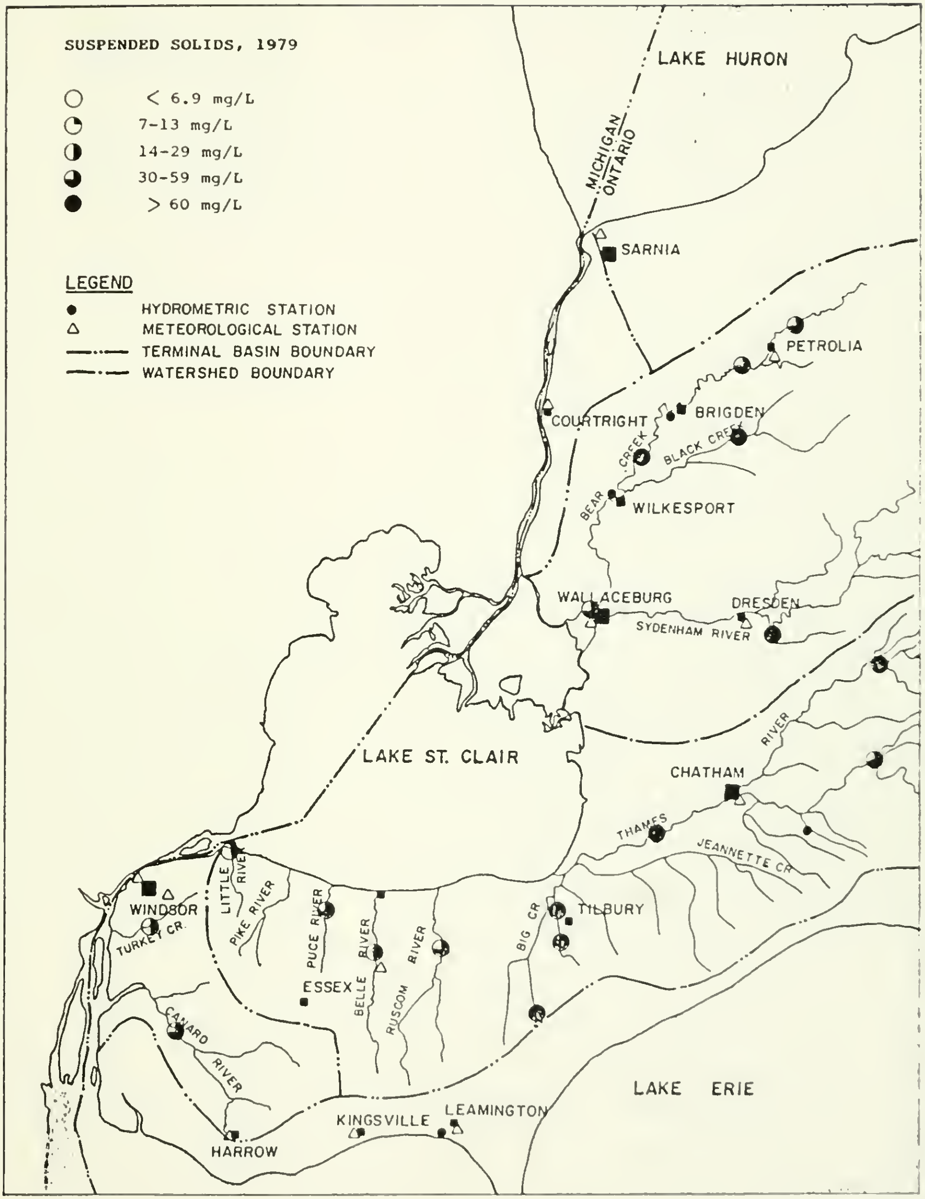


Figure 2.5.3 1979 Suspended Solids Data Summary

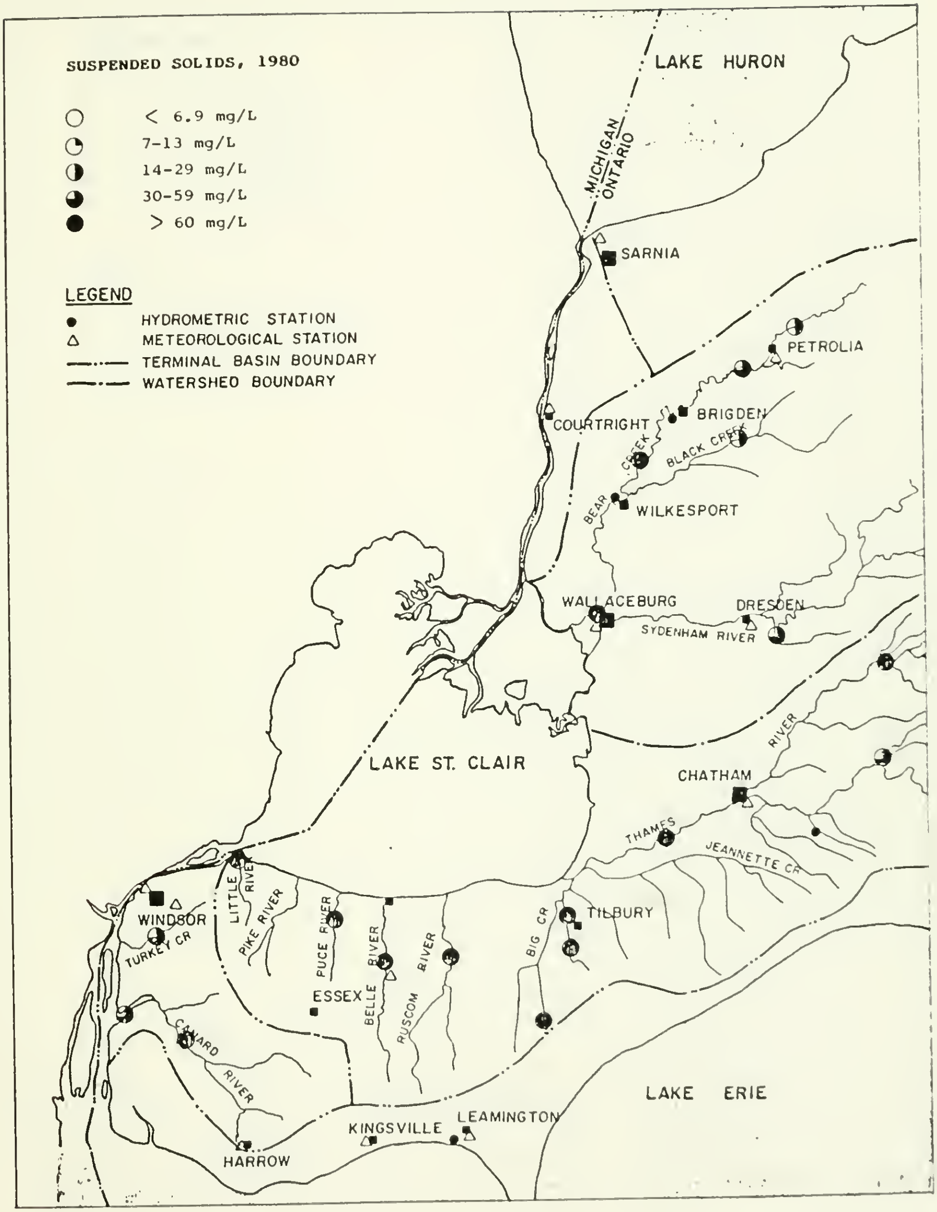


Figure 2.5.4 1980 Suspended Solids Data Summary

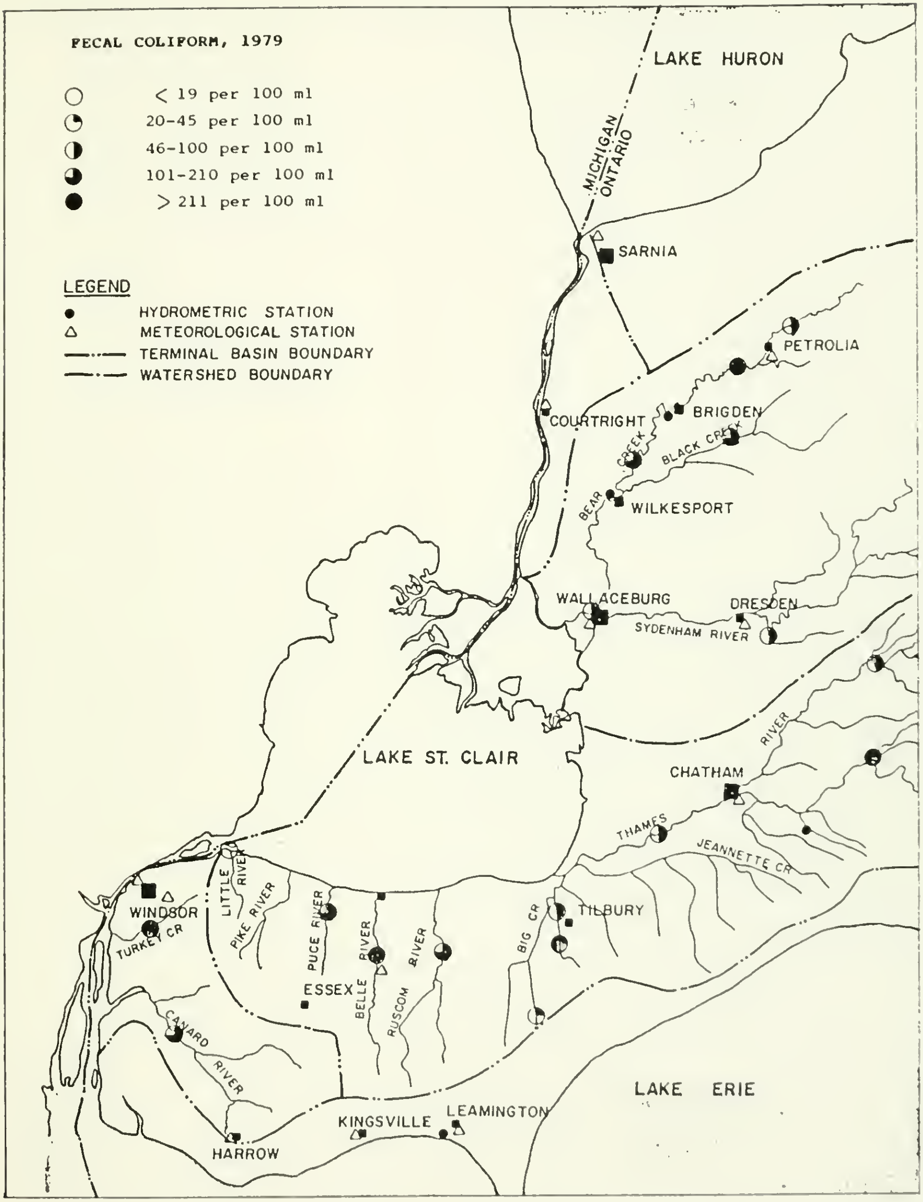


Figure 2.5.5 1979 Fecal Coliform Data Summary

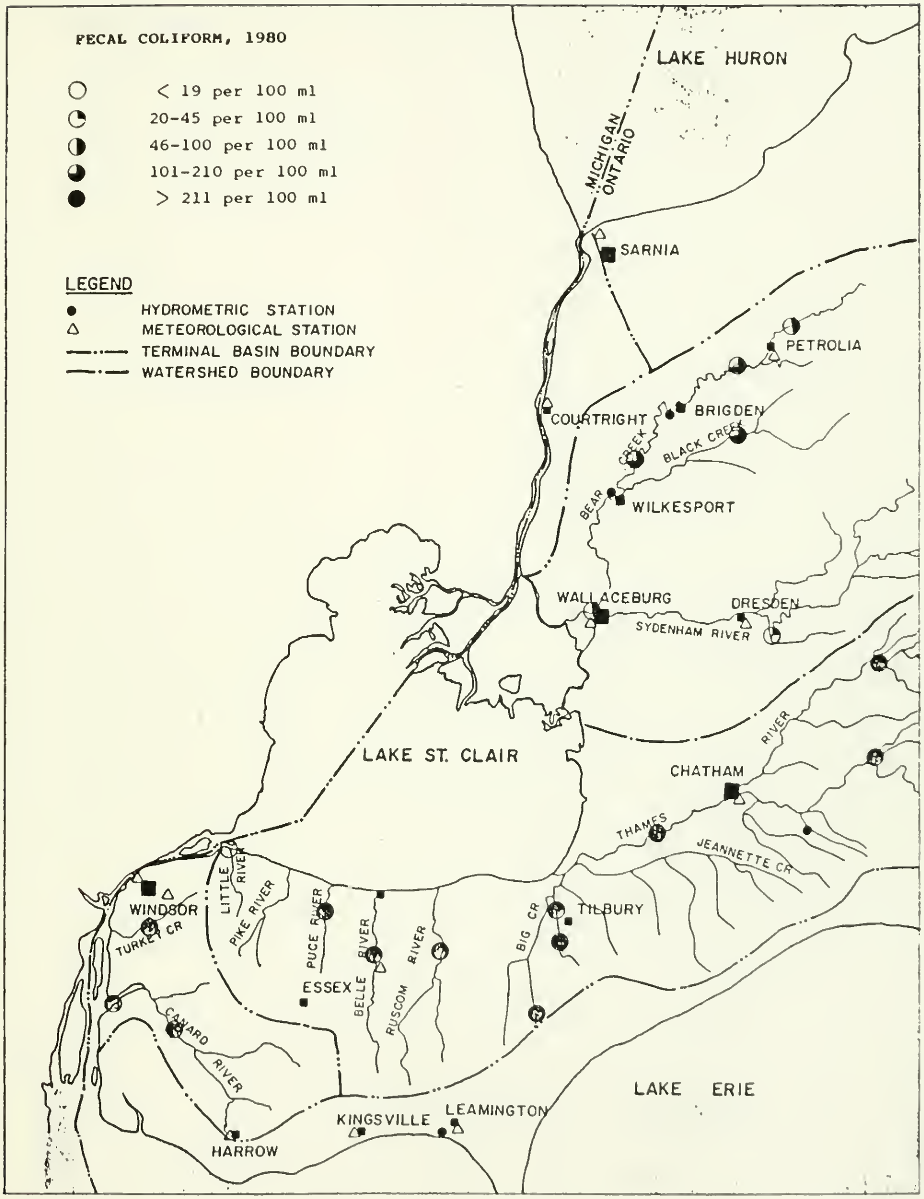


Figure 2.5.6 1980 Fecal Coliform Data Summary

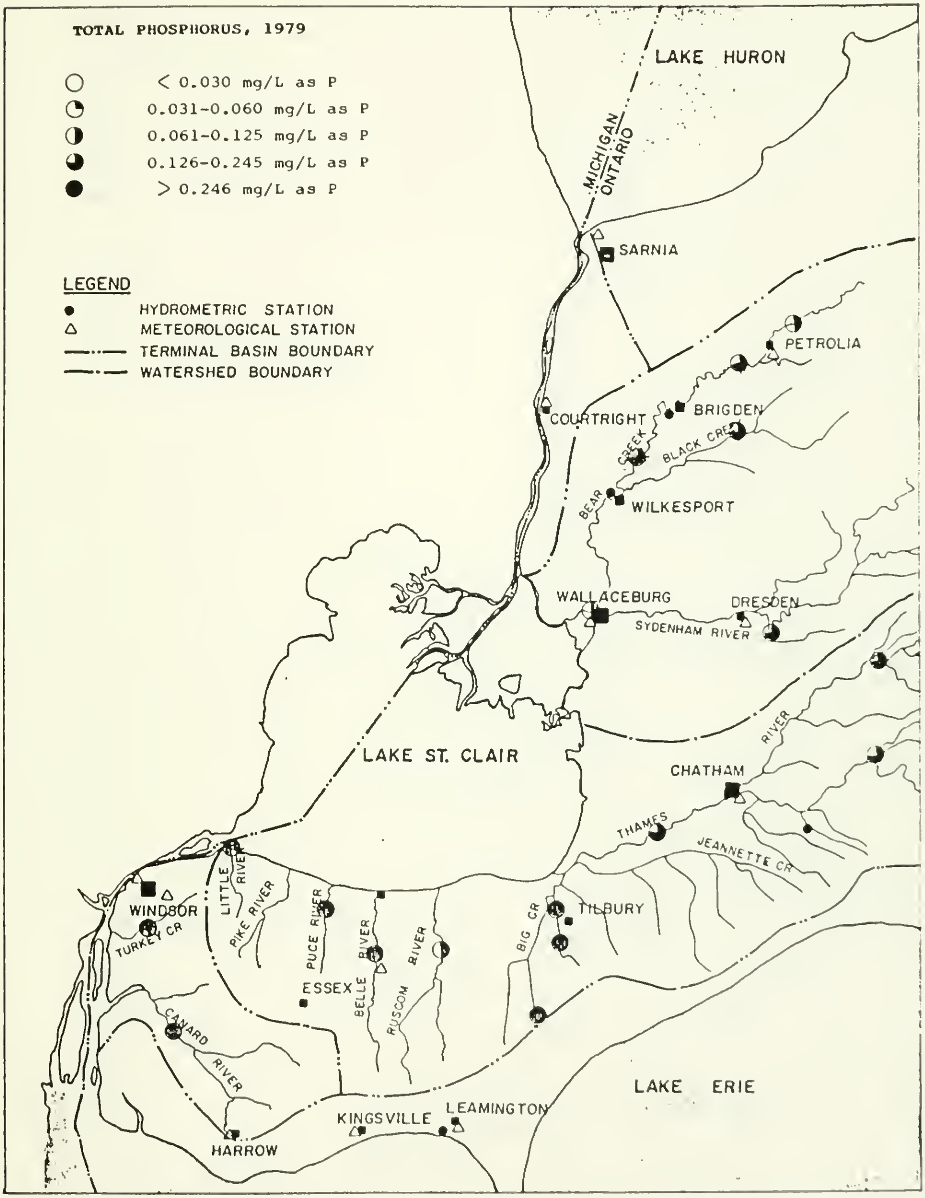


Figure 2.5.7 1979 Total Phosphorus Data Summary

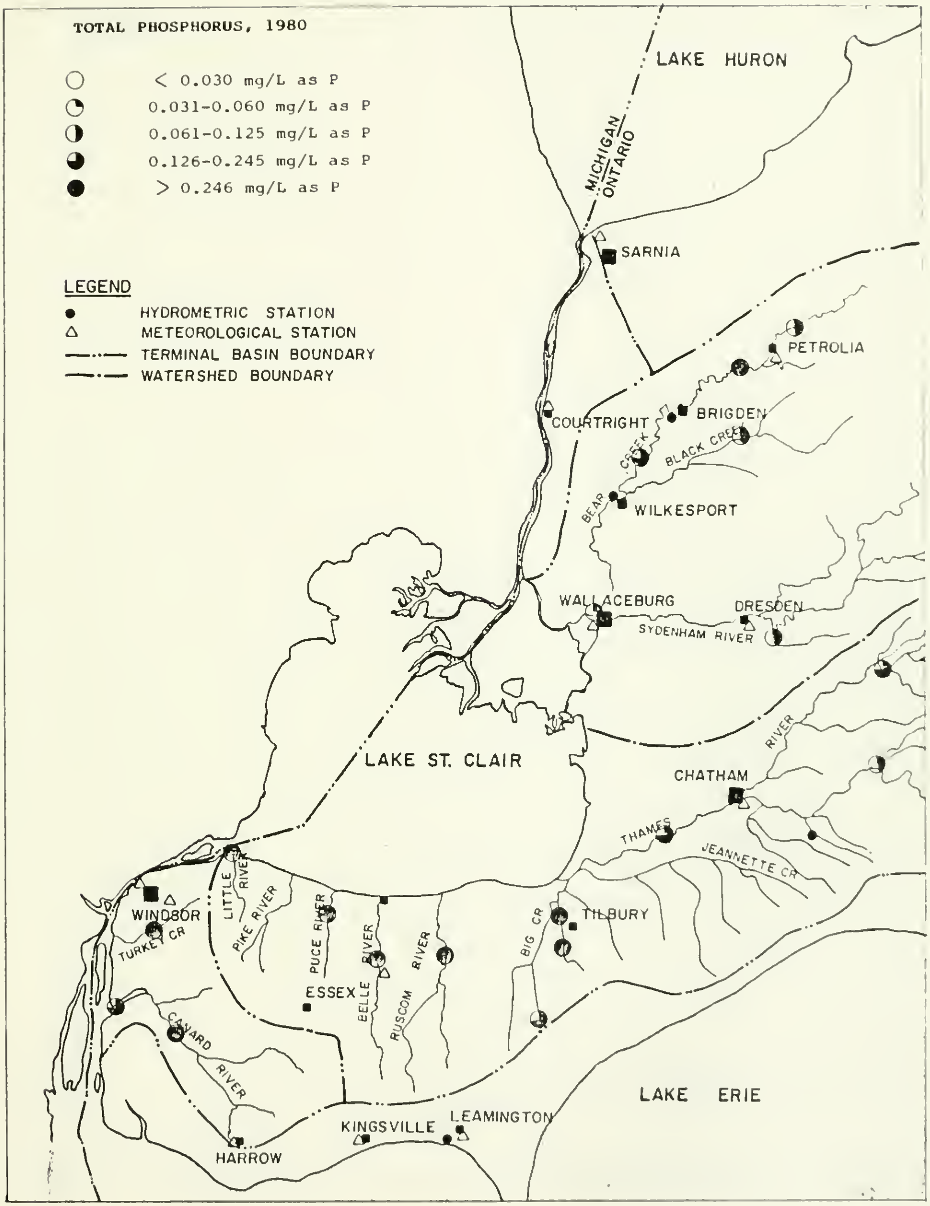


Figure 2.5.8 1980 Total Phosphorus Data Summary

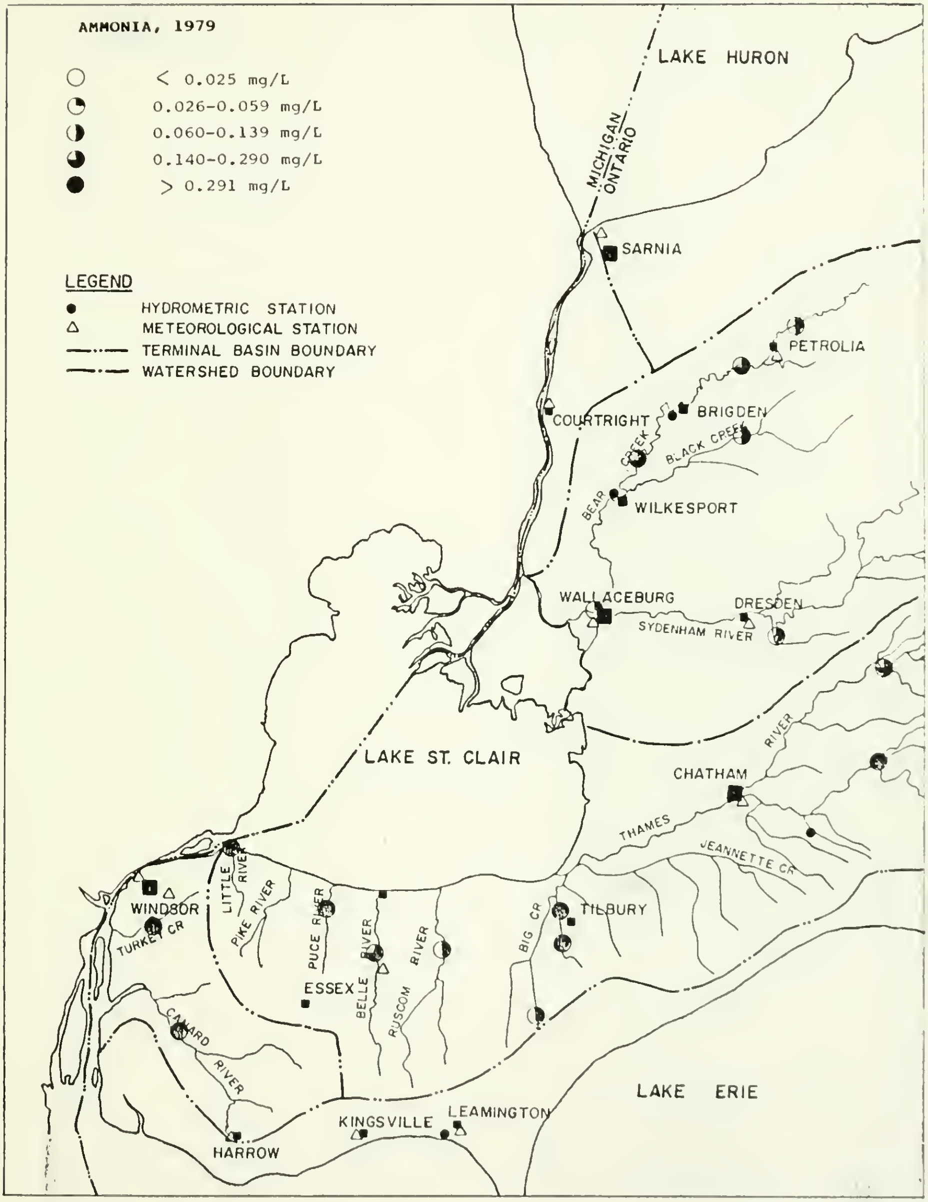


Figure 2.5.9 1979 Ammonia Data Summary

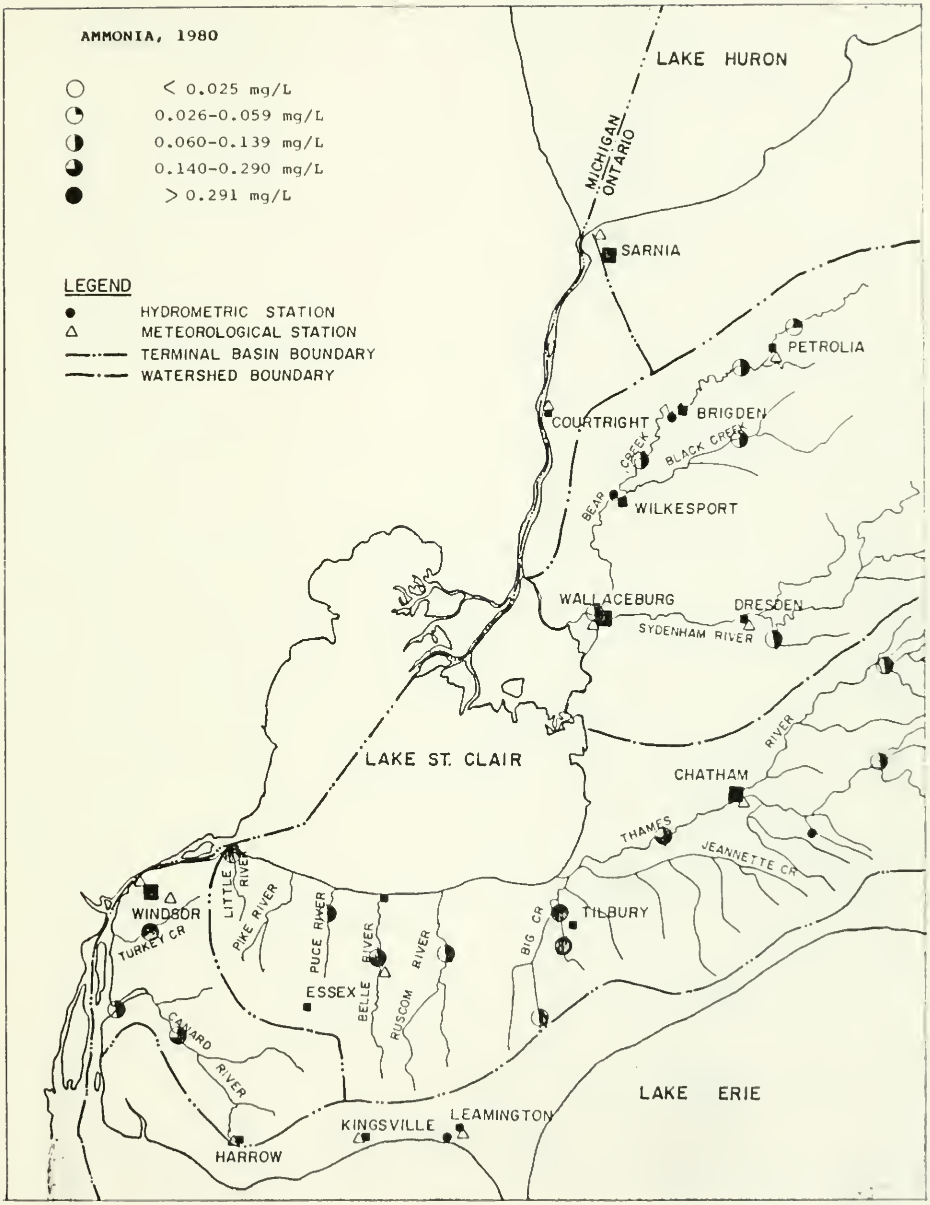


Figure 2.5.10 1980 Ammonia Data Summary

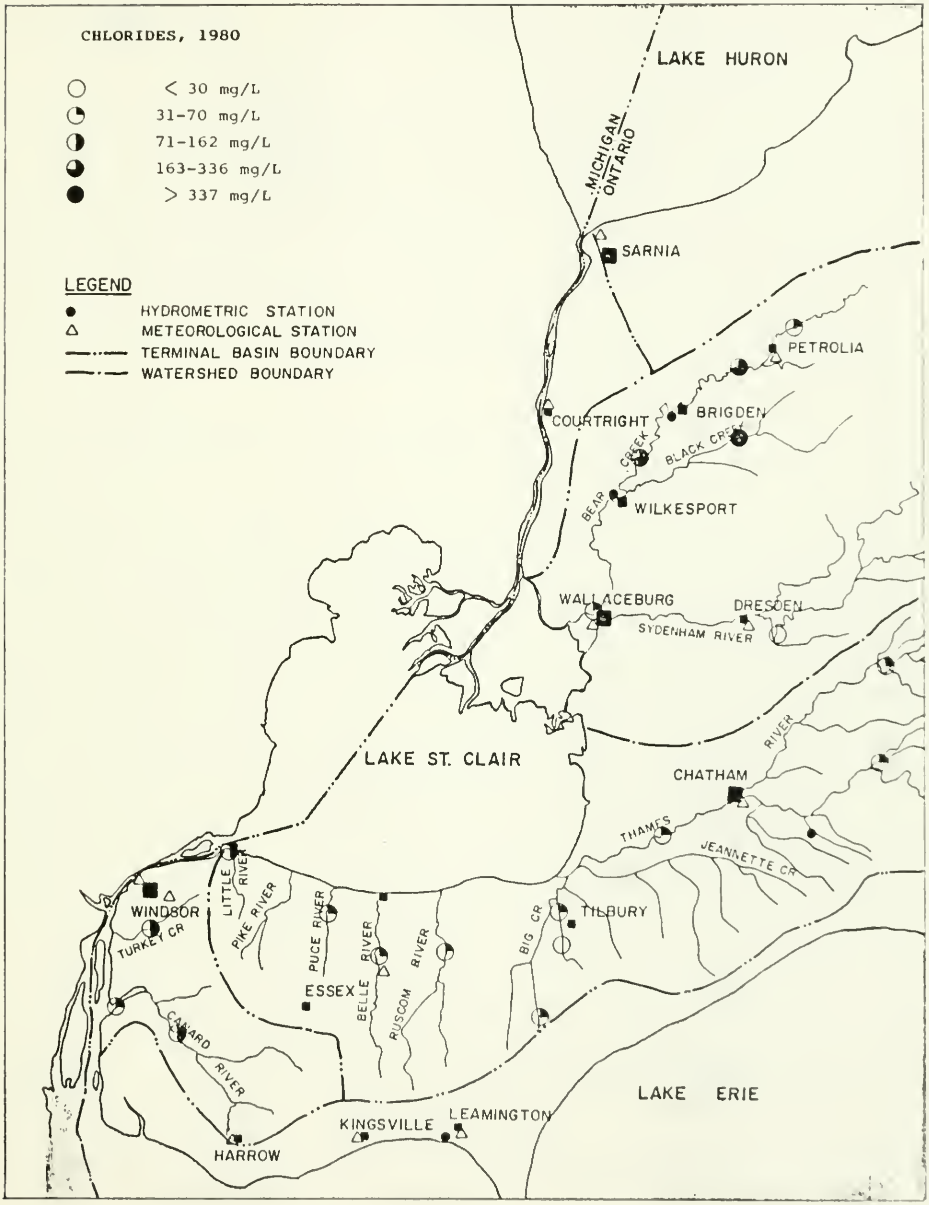


Figure 2.5.11 1980 Chloride Data Summary

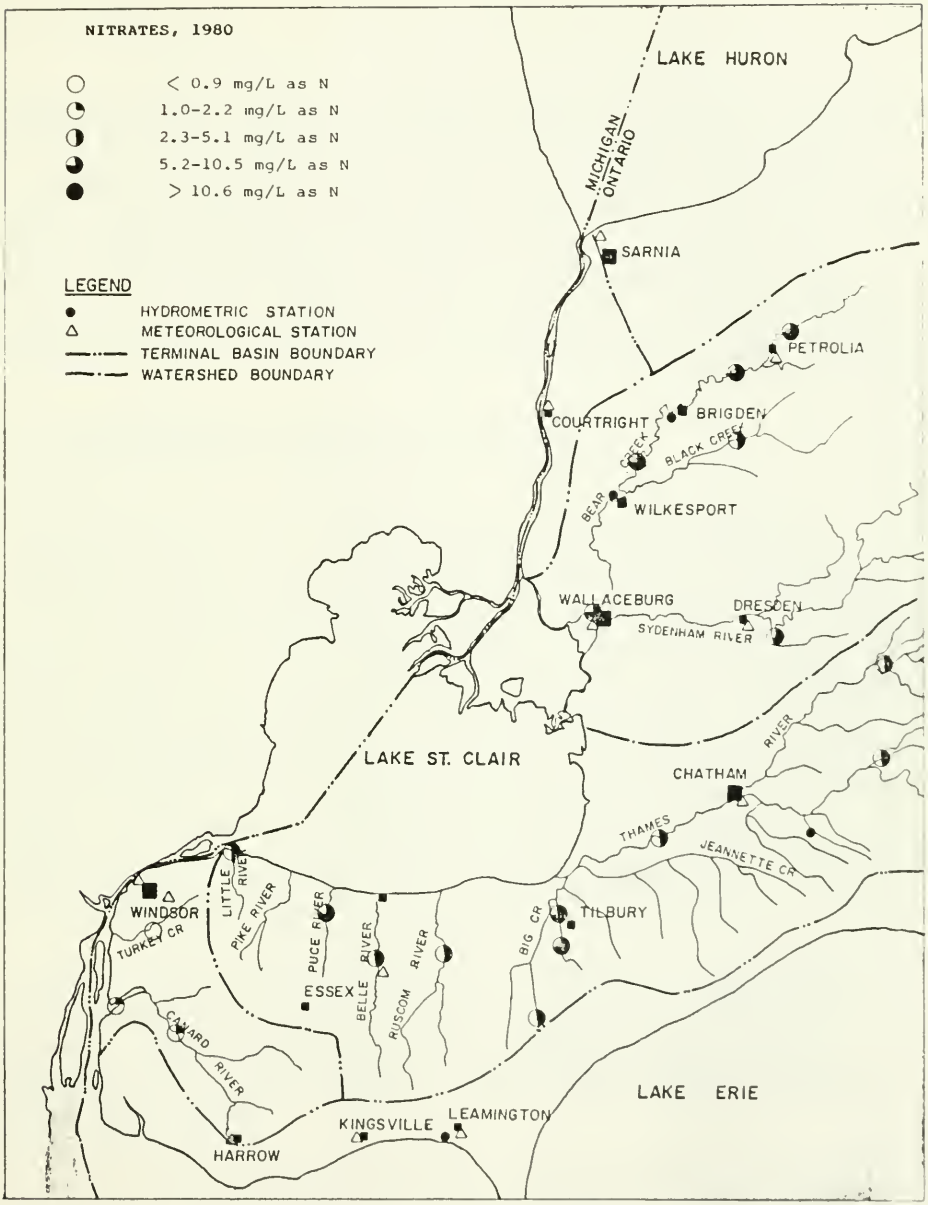


Figure 2.5.12 1980 Nitrate Data Summary

Several studies have been conducted examining the water quality of the St. Clair and Detroit Rivers. Water quality summaries for the Detroit River (MOE, 1976a) and the St. Clair River (MOE, 1976b) were examined. A detailed investigation of the St. Clair River, the St. Clair River Organics Study, resulted in the publication of six reports. These reports included studies on Biological Survey 1968 and 1976 (MOE, 1979) and Identification and Quantitation of Organic Compounds (Banner and Meresz, 1981).

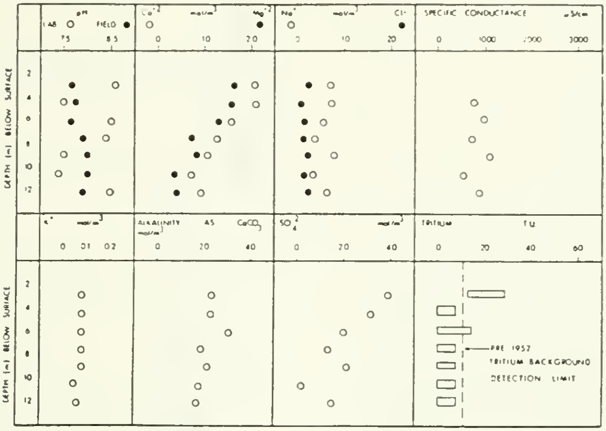
2.6 Ground Water Quality and Geochemistry

The ground water geochemistry of the overburden in the Sarnia-Windsor area is largely determined by the physical characteristics of the thick clay sequences in the overburden. As will be described later, the age of pore waters in the intact clay tills are likely similar in age to the period of deposition and therefore the water geochemistry reflects the influences of infiltration and diffusion. Profiles of the major ion contents of shallow ground waters for four sites in the Sarnia-Windsor area are presented in Figure 2.6.1 (from Hydrology Consultants, 1984) and Figure 2.6.2 (from Desaulnier et al., 1981). Representative overburden major ion concentrations for ten sites in the Sarnia-Windsor area are given in Table 2.6.1.

From the water quality profiles it is apparent that changes in the geochemistry occur with depth. Chloride concentrations increase with depth while calcium, magnesium and sulphate typically have a near maximum concentration in the shallow subsurface waters.

Desaulnier et al. (1981) has shown that the increasing chloride concentration with depth can be extrapolated to the chloride concentrations of the fresh water aquifer. The increasing profile has been attributed by Desaulnier et al. (1981) to upward

WELL OW26



WELL OW27

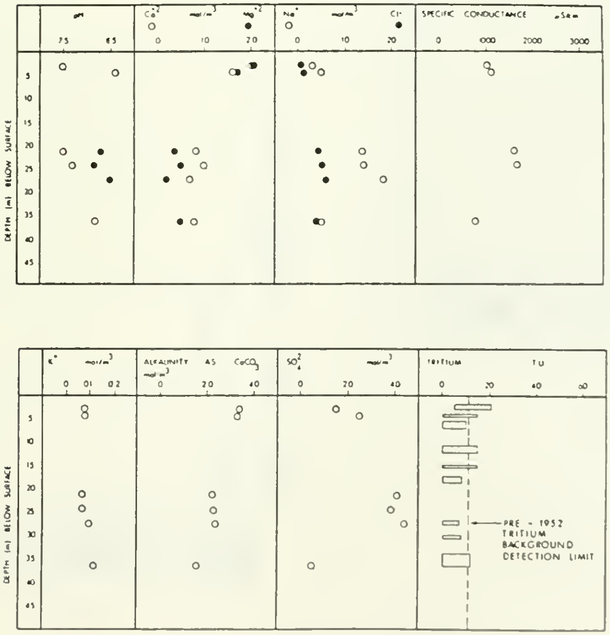


Figure 2.6.1 Representative Ground Water Chemistry Profiles for the Windsor-Sarnia Area (Hydrology Consultants, 1984)

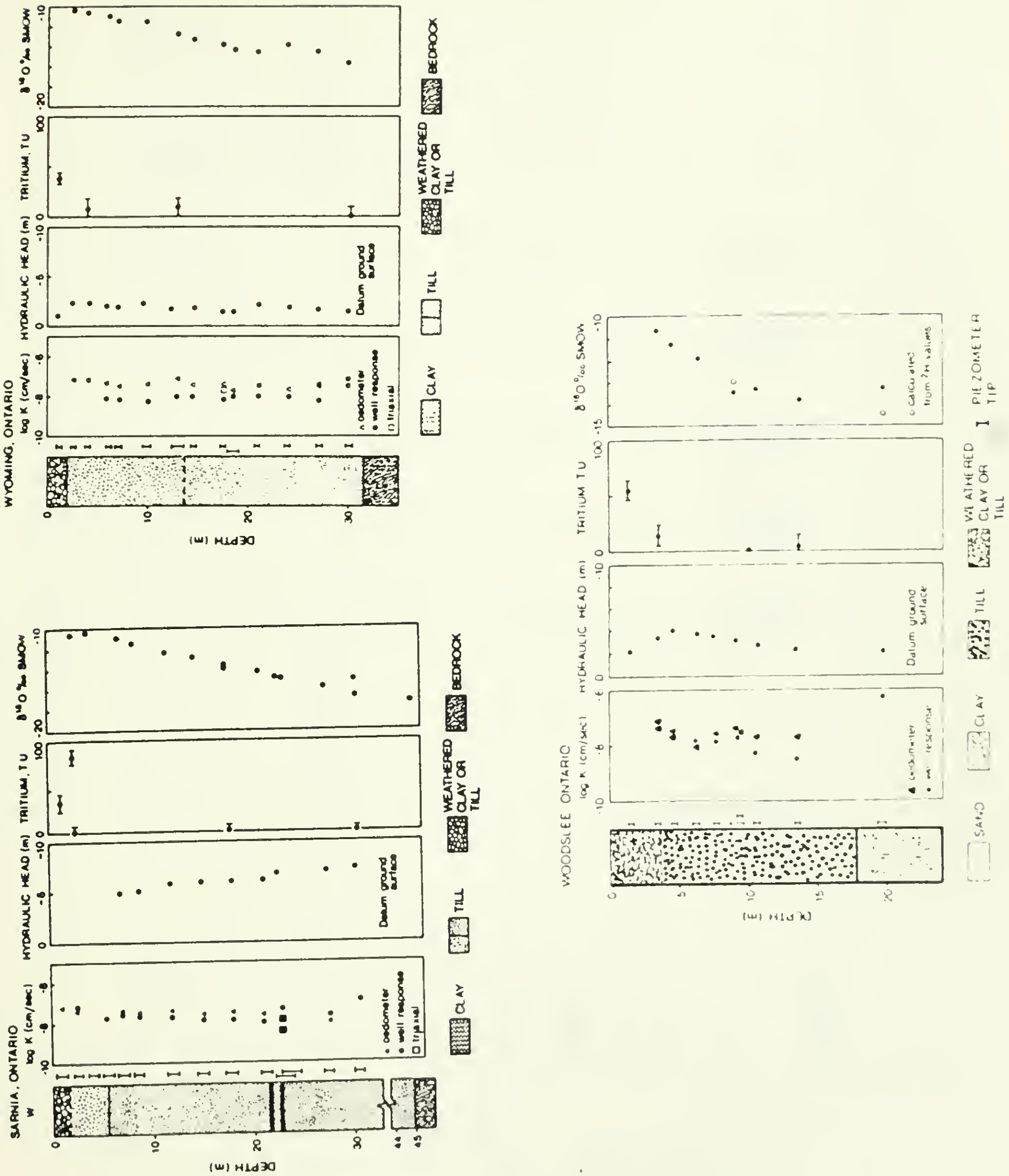


Figure 2.6.2 Representative Ground Water Chemistry Profiles for the Windsor-Sarnia Area (Desaulnier et al., 1981)

Table 2.6.1 Representative Overburden Ground Water Quality (in mg/l unless noted)

Source	Location	pH	E.C. uS/cm	Ca	Mg	Na	Cl	SO_4	Alk $CaCO_3$	Total N	K
Dominion Soils, 1984	Polysar Ltd.	7.7	-	56	-	78	139	37	136	1.23	4.0
MacLaren, 1982	Shell, Corunna	7.0-7.2	980-2000				2		374-465	0.3-3.8	
O.H. Materials, 1984	Welland Chemical	6.7	-	250	110	61.5	890	225	411	-	8.7
Conestoga-Rovers and Assoc., 1979	Johnson Construction Co. Ltd.	8.3	950	154	15	17.6	0.3	325	446	-	5.0
Gartner Lee Associates, 1981	Ridge Landfill	-	2810	-	175	28	8.4	1510	-	-	18
Golder Assoc., 1981	Allied Chemical	7.3 7.5	1350 1600	180 170	50 260	140 64	95 38	400 1100	- -	- -	2 12
Goodall and Quigley, 1977	Confederation Road	-	-	29	30	80	-	-	-	-	4
Morrison Beatty Ltd., 1984	Warwick Landfill	7.5	510-6300	208	202	142	20	55-4500	-	-	-
Conestoga Rovers & Assoc., 1980	Petrolia	8.0	910	119	30	61	31	170	354	-	3.2
Hydrology Consultants, 1984	Tricil	-	-	41-121	15-68	470	10-89	31-152	-	-	-
		-	-	35-85	54-100	43-83	14-47	53-380	-	-	-
		8.8	-	8.4	3.9	157	163	40	190	-	16
		8.2	-	10	4.9	166	156	40	290	-	5.4
	Cole Well near Tricil	7.9	1020	121	36.4	47	64	152	287	-	6.65

diffusion of chloride rich bedrock waters. Chloride concentrations typically range from about 1 to 200 mg/l with the higher concentrations occurring at depth.

Calcium, magnesium and sulphate concentrations reach a maximum concentration in the local ground water flow system. In this zone it is likely that the water chemistry is influenced by weathering processes and increased fracture flow. Flushing of infiltrating precipitation and a horizontal component of flow likely increases the specific ion concentration in this system. Deeper concentrations will reflect the composition of the original pore water and geochemical processes within the clay tills. The slow migration of waters through the intact clays allow kinetic processes such as oxidation of organic matter, carbonate dissolution and precipitation, sulphide mineral oxidation, gypsum dissolution and precipitation and cation and anion exchange to gradually reach an evolutionary equilibrium.

Calcium and magnesium concentrations typically range from 10 to 200 mg/l which is within the maximum desirable concentration. Sulphate values range from about ten to several thousand milligrams per litre. Sodium has concentrations of 25 - 400 mg/l and potassium is present in concentrations less than 20 mg/l. Specific conductivity is usually quite high with a range of 500 - 3000 uS/cm. Total dissolved solids are high in association with the electrical conductivity and major ion concentrations.

The water quality in the shallow overburden is general poor and dug wells in this system are usually used for livestock, washing, or reserved supply. The composition of the overburden ground waters vary throughout the study area but are typically calcium-magnesium-sulphate-bicarbonate waters which may be indicative of the bedrock composition which in the north is predominantly shale and in the south is dolomitic and shaley limestone.

Regional ground water quality for the fresh water aquifer was examined using published data of municipal supplies, (MOE, 1977) data obtained from the Ontario Ministry of the Environment and various industrial and consulting reports. Representative data are given in Table 2.6.2.

The data obtained from the Ministry of the Environment were collected as part of an ongoing monitoring program in Lambton County currently conducted by Cambrian Disposals Ltd. and the Ministry. Data exist back to 1971 but only data from 1981 on were included. The program focuses on private wells located near deep brine disposal wells and the Tricil disposal site. Monitoring is conducted quarterly.

The samples are analysed by the Ministry of the Environment laboratories for major cations, major anions, pH and conductivity. The results indicate that the ground waters have elevated levels of chloride and sodium, low sulphate concentrations and low concentrations of calcium and magnesium (i.e., soft waters).

Chloride concentrations typically range from below 100 mg/L in a few cases to 1000 mg/L. The majority of wells sampled exceed maximum desirable concentration set by the MOE Ontario Drinking Water Objectives (MOE, 1984b) of 250 mg/L.

Sodium concentrations range from a recorded low of 4.9 mg/L to a high of 780 mg/L. The majority of wells range from approximately 200 mg/L to 400 mg/L. Sodium is not considered to be a toxic metal however, persons suffering from hypertension or congestive heart failure may require a sodium restricted diet in which case sodium from drinking water could become significant. MOE (1984), therefore, recommends that a sodium concentration in excess of 20 mg/L be reported to local physicians so that people can be informed.

Table 2.6.2 Representative Fresh Water Aquifer Water Quality (in mg/l unless noted)

Source	Location	pH	E.C. (uS/cm)	Ca	Mg	Na	K	Cl	SO_4	Alk	Fe
Hydrology Consultants, 1984	Tricil	-	-	15-90	5.4-36.4	168-775	-	130-1270	0.5-5	-	0.07-1.9
Enviroclean, 1984	Long Well Tricil Area	7.9	1140	26.5	8.6	214	2.65	198	1.0	218	1.18
	Allingham Well Tricil Area	7.9	865	17.0	7.2	171	1.50	132	2.0	-	1.42
	Bugler Well Tricil Area	7.8	1085	11	5	230	1.4	194	1	-	0.28
	Bahlmann Well near Cambrian Disp. Ltd. #6 Well	6.9	650	69	32	11	2.4	33	96	-	2.22
	Rosina Well near CDL#1	7.1	810	102	40	20	1.1	20	65	-	0.04
Berry, 1977	Private Well Twp. Bosanguet	7.5	-	-	-	-	-	10.5	3.5	217	0.08
	Rondeau Bay Estates Twp. Harwick	7.8	-	-	-	-	-	653	3	223	0.15
Morrison & Beatty, 1984	Warwick Landfill	7.9-8.3	1000-1434	10-50	10-50	180-190	-	57	350	-	-
Gartner Lee Associates, 1981	Ridge Landfill	-	1330	-	30	85	9	141	200	--	
Golder Associates, 1981	Allied Chemical	7.3	1200	180	50	140	2	100	380	-	-

Sulphate concentrations range from less than 1 mg/L to 130 mg/L. The majority of wells report values of less than 1 mg/L. These values are well below the maximum desirable concentration of 500 mg/L.

Iron concentrations vary from less than 0.04 to 3.2 mg/L. On the last analysis reported, nine out of ten of the wells exceeded the maximum desirable concentration of 0.3 mg/L.

Calcium concentrations and magnesium concentrations range from 11 mg/L to 117 mg/L and 5 mg/L to 54 mg/L respectively. The low values indicate the water is relatively soft.

Data obtained from MOE (1977) confirm the above trends and indicate that the ground water quality is fairly uniform throughout the study area. Significant local variations can however be expected.

Generally it can be stated that the ground water in the study area is a soft water that contains elevated concentrations of sodium, chloride and iron. These elevated concentrations are not a risk to health but tend to reduce the aesthetic quality of the water.

Vandenberg et al. (1977) reported on a detailed geochemical study on the fresh water aquifer conducted in association with deep disposal wells. This study examined over 150 well samples in Lambton County and determined the major ion chemistry. Seven distinct chemical types were determined as is shown in Figure 2.6.3. Group A are bicarbonate-chloride waters while Group B are bicarbonate-sulphate-chloride waters. When the areal distribution of the chemical types were placed on a map (Figure 2.6.4) Vandenberg et al. (1977) were able to produce inferred ground water flow directions for the fresh water aquifer in

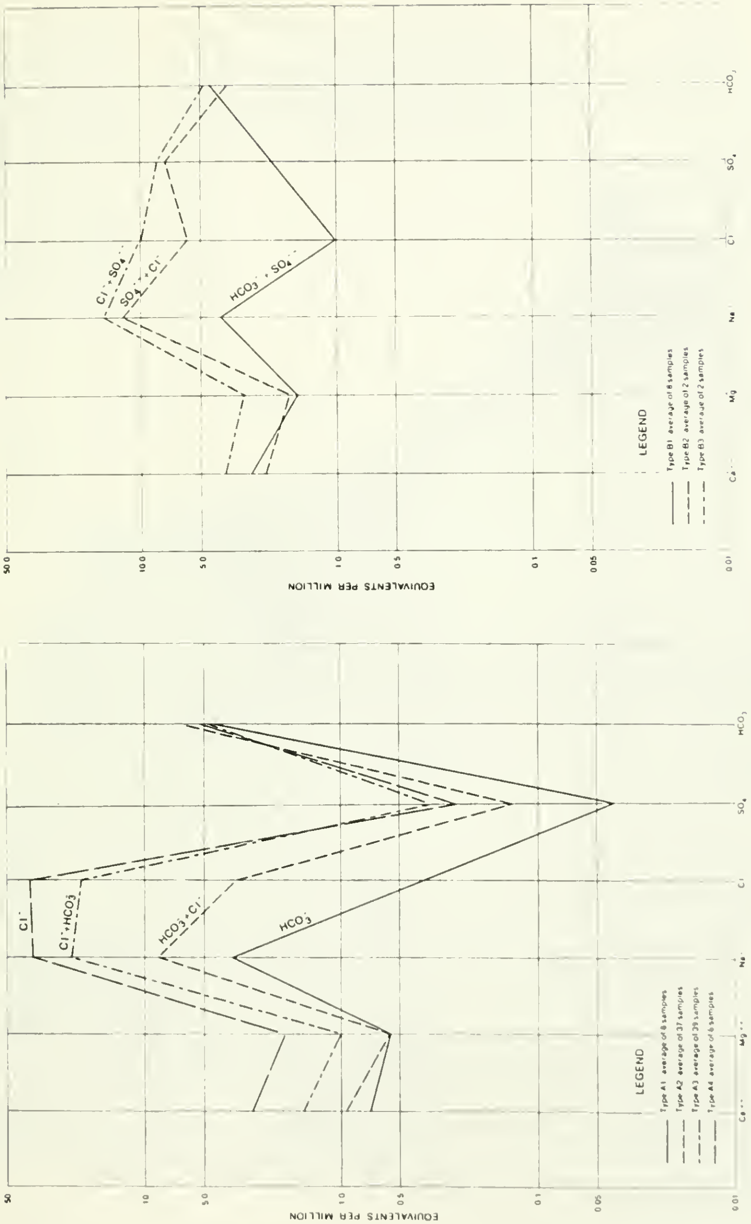


Figure 2.6.3 Geochemical Water Types for the Fresh Water Aquifer (Vandenburg et al., 1977)

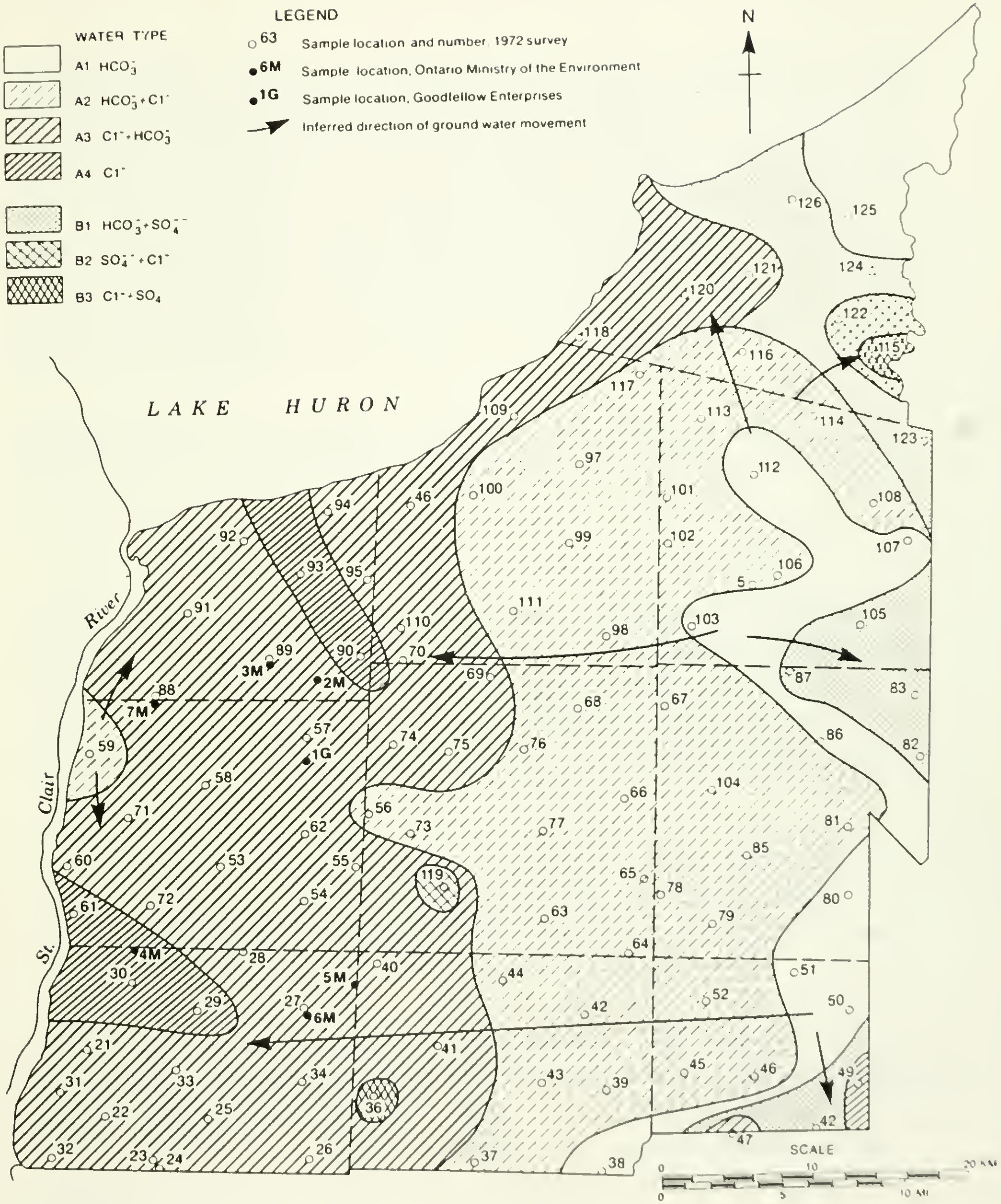


Figure 2.6.4 Areal Distribution of Geochemical Water Types for the Fresh Water Aquifer (Vandenburg et al., 1977)

Lambton County. These directions essentially coincide with the piezometric flow directions shown in Map 071-6-L. It is interesting to note that Group A waters correspond to the shale locations of the Kettle Point and Hamilton Formations while Group B is associated with the limestones of the Hamilton Formation. The flow directions essentially follow the chemical evolution of the waters from the recharge areas and therefore the contact time with the soil and rock is likely the factor controlling the ground water chemistry (Vandenberg et al., 1977).

A discussion of contaminant transport, attenuation mechanisms and two-phase flow is found in Appendix 2.

2.6.1 Isotopic Analysis

Environmental isotopes have been used in the Sarnia-Windsor area to identify the age and origin of pore waters in the clay tills. The majority of the studies have involved the scientists of the University of Waterloo and much of what is contained in this section is derived from reports by Desaulnier et al., (1981) and Cherry et al. (1980).

Environmental isotopes such as oxygen-18 (^{18}O), tritium (^{3}H), deuterium (^{2}H) and carbon-14 (^{14}C) have been used for hydrogeological purposes since the early 1950's. ^{3}H and ^{14}C are radioactive and decay with time while ^{18}O and ^{2}H are nonradioactive and are stable with time. ^{3}H and ^{14}C have been used to date ground waters. ^{18}O and ^{2}H are used as indicators of ground water source areas and changes in the water since it was "formed". The interested reader is directed to Fritz and Fontes (1980) for more information on isotope geochemistry and its applications to ground water studies.

Tritium has been used at a number of sites in the Sarnia-Windsor area to distinguish between waters that have entered the aquifer prior to 1953 (prebomb water) and those that enter the aquifer after 1953. Atmospheric waters after 1953 contain measurable quantities of tritium due to the explosion of atomic bombs while pre-1953 waters are relatively absent of tritium. Therefore the presence of tritium indicates relatively young waters.

Desaulnier et al. (1981) , Cherry et al. (1980) and Hydrology Consultants (1984) have provided detailed studies of tritium concentrations at a number of sites in the Sarnia-Windsor area. Golders and Associates (1981) and Gartner-Lee Associates (1981) have also conducted less detailed studies. Examples of the tritium concentrations with depth are given in Figures 2.6.1 and 2.6.2. The important point to note in the tritium profiles is the lack of tritium below 6 m depth. This depth likely conforms to the depth of weathering and fracturing in the local ground water system and therefore the waters in this zone are relatively recent (i.e., post-1953). Waters at greater depths are pre-1953. Using the distance the tritium front has traveled in thirty years a maximum velocity of about 20 cm/yr could be calculated. This velocity however is higher than that predicted by hydraulic flow and represents the significant transport effects of diffusion within the clay tills.

Oxygen-18 profiles for the Sarnia-Windsor area (Figure 2.6.2) illustrate a decreasing trend with depth. The trend is indicative of a change from present precipitation ^{18}O concentrations of about -18 to -6 $^{\circ}/_{\circ\circ}$ to values of -15 to -20 $^{\circ}/_{\circ\circ}$, representative of much cooler climates. The deeper ground waters are probably original formation waters based on their isotopic composition.

Carbon-14 has been used to provide ground water ages of the intact clay tills based on radioactive decay dating techniques. From Desaulnier et al (1981), ^{14}C ages and a profile are presented in Figure 2.6.5. The estimated ages range from 8,760 to 9,870 years before present which coincides with the approximate age of the formations. It is estimated that the formation of these clay tills occurred approximately 11,000 to 14,000 years ago.

In summary, the isotopic compositions of the overburden pore waters have lead to several conclusions regarding the characteristics, age and movement of the ground water. Shallow ground waters are relatively young waters and the depth of these waters is influenced by the extent of weathering and fracturing. Diffusion in the clays has assisted the migration of environmental isotopes. Deeper ground waters originated in cooler climates likely during the early Holocene or late Pleistocene and are approximately 8700 to 9800 years old.

2.7 Monitoring Programs

Monitoring of ground water and surface water is conducted through a number of programs throughout the study area.

Regional surface water quality is assessed by a program initiated in 1964 by the Water Resources Branch of the Ministry of the Environment. The data collected are published in a yearly volume "Water Quality Data for Ontario Lakes and Streams". The most recent volume was published in 1981 and gives 1980 data. The data result from a routine sampling program designed to provide a long-term record of water quality information at specific points on rivers and inland lakes in Ontario. The sampling locations were selected to provide data 1) on the materials discharged from tributary

Carbon-isotope analyses and corrected ages

Site	Well type*	Sample No.	Depth (m)	^{14}C activity (PMC)	$\delta^{13}C$ (‰ PDB)	Corrected age (yr. B.P.)
Sarnia	a	*SI-80*a	24	10.4	−9.03	9,840
Sarnia	b	*SI-100*x	40	0.2	+15.4	—
Woodslee	a	WO-*65*	20	18.7	−12.5	8,770−9,870
Wyoming	a	YO-*45*	14	22.5	−16.8	9,750
Wyoming	a	YO-*60*	19	15.7	−10.1	8,760

*a = 5.2-cm I.D. piezometers installed at study site, b = domestic well located near study site.

Sarnia study site.

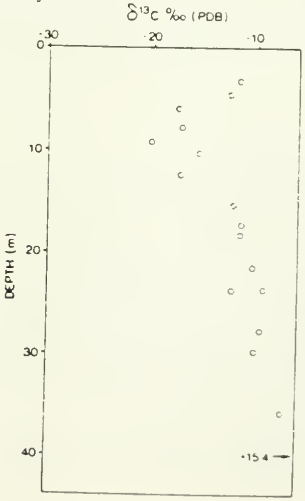


Figure 2.6.5 Carbon-14 Profile and Estimated Carbon-14 Ages for the Windsor-Sarnia Area (Desaulnier et al., 1981)

streams to terminal basins 2) to monitor the effects of wastewater discharges on watercourses 3) that can be considered generally representative of surface water quality conditions in a certain area. The samples taken are analysed for some or all of the parameters listed in Table 2.7.1.

The sampling locations within the Sarnia-Windsor study area are shown on Figure 2.3.1.

The water quality of the St. Clair River was examined through a detailed study known as the St. Clair River Organics Study. This program was initiated by the Ministry of the Environment in 1977 to investigate and confirm the presence and significance of organic compounds identified in the river and to establish the relation of the organics downstream and the potential bio-accumulation of such compounds by fish. The results are available in a series of six reports.

The water quality of the St. Mary's River is under constant investigation by the MOE. Detailed investigations conducted in 1973 and 1974 are discussed by Hamdy et al (1978). This report presents data compiled prior to the completion of several major abatement programs and therefore provides a basis for comparison with water quality conditions after the effects of these remedial measures have been realized. Subsequent MOE studies in 1975 and 1976 indicated that water quality remained unchanged, however, noticeable changes were expected in results obtained in five monitoring surveys completed in 1977.

Ground water sampling of private wells is conducted by Ministry of the Environment personnel as the need arises. Concerns expressed by individuals are addressed if it is felt the concern is warranted. Results are on file with the Ministry.

Table 2.7.1 Surface Water Quality Parameters

- Total coliform
- Fecal coliform
- Pseudomonos aeruginosa
- Biochemical Oxygen Demand (BOD)
- Total Phosphorus
- Filtered reactive phosphate
- Filtered ammonia
- Total Kjeldahl nitrogen
- Filtered nitrate and nitrate
- Total Solids
- Suspended solids
- Dissolved solids
- Conductivity
- Turbidity
- Chlorides
- Sulphates
- Unfiltered reactive silicates
- Acidity
- pH
- Total iron
- Phenols
- Hardness
- Calcium
- Magnesium
- Colour
- Potassium
- Sodium
- Total Organic Carbon (TOC)
- Chemical Oxygen Demand (COD)
- Solvent extractables
- Arsenic
- Mercury
- Aluminium
- Chromium
- Copper
- Lead
- Cadmium
- Zinc
- Manganese
- Nickel
- Flouride
- Cyanide
- Cobalt
- PCB
- PCP
- 2,4,5-T

Monitoring of ground water and surface water for evidence of contaminant migration and to ensure the safety of private water supplies is in effect at a number of waste disposal sites within the study area. The sites that are monitored are listed in Table 2.7.2. The monitoring is predominantly done by the site owner or a representative of the owner in conjunction with the Ministry. The monitoring program at the sites is very site specific and no strict guidelines exist that require monitoring until a problem is identified. When monitoring is initiated a detailed analysis is conducted and tests are done for major cations, major anions, organics and metals. When the extent of the contamination, rate of migration and ground water flow regime is determined the detail of the analysis is altered if warranted. In certain circumstances the samples are, subsequently, only analysed for indicator parameters, whereas in other situations, more detailed analysis may be required. Also, the frequency of sampling is governed by the individual circumstances. Monthly, quarterly, yearly or as required sampling programs are initiated depending on the circumstances.

One ground water program presently in effect involves monitoring of private wells surrounding the deep disposal wells. Cambrian Disposals Ltd., in conjunction with the Ministry, have been conducting quarterly sampling throughout Lambton County since 1971. No contamination has been identified to date.

Another program presently underway involves sampling of wells around the Algoma Steel site. Testing is predominantly for polyaromatic hydrocarbons (PAH). Detailed results are presently not available.

Table 2.7.2 Waste Disposal Sites Monitored Regularly

Site No.	Certificate of Approval	Site	Monitoring Conducted
L-1	A030104	Dow Chemical	G & S
L-3	A030107	Polysar Ltd.	S
L-4	A030303	Town of Petrolia	G & S
L-5	A030330	Canflow Services	S
L-10	A031806	Tricil Ltd.	G
L-11	A031807	Cambrian Disposal	G
L-13	A031810	Unitec Inc. (Holmes Insulation)	G
L-16	A031819	Shell Canada	G & S
L-18	A032001	Cambrian Disposal	G
L-21	A032006	L & E Solid Waste	G & S
L-22	A032007	Cambrian Disposal	G
L-23	A032008	Cambrian Disposal	G
L-24	A032010	Cambrian Disposal	G
L-25	A032013	Esso Petroleum	G & S
E-1	A010201	Allied Chemical	G & S
E-3	A011501	Essex County	G & S
E-5	A010103	Windsor -Malden	S
A-1	A560101	Algoma Steel	G & S

G = ground water
S = surface water

In general, the foundation of an extensive network for monitoring of ground water and surface water is in place. The extent of monitoring, the detail of the analysis and the type of monitoring is however, always very site specific. Detailed monitoring programs must be established for individual site specific cases.

2.8 Waste Containment Methodologies

The objective of this section is twofold. The primary objective is to document the waste containment methodologies currently in use in the study area together with their applicability to and compatability with the various waste streams present. The existing methodologies are discussed in terms of their performance as documented to date.

The second objective of this section is to review alternative waste containment methodologies which are relevant to the waste disposal situation in the study area. Alternative methodologies are compared with each other and with the currently utilized methods of waste containment. Interaction between specific groups of chemicals (i.e., organics, acids) and components of the various waste containment systems are identified and discussed.

2.8.1 Existing Waste Disposal Methodologies

There is essentially one waste disposal methodology which has been adopted at the majority of sites in the study area. This methodology consists of utilizing the natural geologic materials at the site for waste containment. The clay till and lacustrine clay present throughout the study area, at depths on the order of 30 meters, has hydraulic properties (i.e., hydraulic conductivities) which make it useful for waste containment. In addition, clay type soils are generally quite good at attenuating the transport of solutes in the subsurface such that the extent of a site impact is further reduced.

The method generally adopted for waste disposal is to excavate to some depth below ground surface at which point the wastes (either liquid or solid) are placed in the open cut or trench. At solid waste disposal sites, a cap of the native excavated material is usually placed over the disposed waste. This promotes run-off of precipitation and reduces infiltration and subsequent leachate generation and travel rates.

Hydrogeologically, the placement of wastes in the clay till results, in most cases, in relatively low solute transport rates by advection in the ground water regime due to the low hydraulic conductivity and relatively high porosity of the porous media. Also, the thick nature of the deposit results in long transport times, under the predominantly downward vertical gradient, to the underlying sand and gravel aquifer situated at the bedrock surface. Capping of the disposal area further reduces the potential for release of environmental contaminants via the ground water regime.

The integrity of the capping material is one of several factors which affect the overall performance of the waste disposal system. In situations where the cover material is of a lesser hydraulic conductivity than the area surrounding the disposal site, either due to inadequate compaction or due to the creation of a composite material from various parts of the excavation (of differing hydraulic characteristics), then a greater relative amount of precipitation may enter the subsurface at the disposal site. As a result, a mounding effect in the water table may be observed at the waste site which leads either to higher ground water flow rates through the site due to the higher hydraulic gradients or to a "bath tub" type effect within the excavation where ground water levels rise above the level of the surrounding water table,

possibly as high as the land surface. Leachate spring may result and waste contaminated water may then be transported from the site overland to the surface water system.

Whether the trenches excavated for waste disposal extend to below the weathered zone (approximately 6 m deep) or not is usually documented although it is thought, for the most part, that disposal operations are within the weathered zone. The implications of wastes being placed in the weathered zone arise due to: (1) the presence of fissures and/or fractures, and (2) the short travel path to the biosphere.

The result of fissures and/or fractures in the vicinity of the wastes is that there exists a potential for a higher effective hydraulic conductivity and porosity (see Section 2.4) which may lead to more rapid transport of solutes dissolved in the ground water. Further implications arise in that separate liquid phases of immiscible fluid may move rapidly along these small openings in the media, due to reduced surface tension in the larger pores. The physical nature of these features (i.e., fracture aperture) and their interconnectivity are key points in assessing the potential impact. These concepts are discussed in greater detail in Appendix 2.

The impact caused by the short travel path to the biosphere is primarily due to diffusive transport of solutes from the waste source. In low hydraulic conductivity environments, such as that created by the clay till, transport of solutes by diffusion, in directions differing from the hydraulic gradient, may be more significant than by advection. In such a case, the distance between land surface and the waste may be an important factor as this represents the shortest route to the biosphere.

Diffusion to the biosphere of dissolved contaminants originating in the waste is most significant in a situation where the wastes are placed close to the land surface and where the water table is close to the surface either due to natural or artificial (i.e., ground water barrier down-gradient) conditions. In a situation where the water table is deep, vertically upward diffusion is not a significant threat due to the discontinuous water phase in the unsaturated zone. When the wastes are placed deep below the ground surface, even with a high water table, the travel time for diffusion is significantly greater due to the longer travel path and enhanced dilution due to diffusion in the horizontal orientation. Further discussions on diffusive transport problems are presented in Appendix 2.0.

In terms of the compatability of the native clay till with the various wastes present, there is generally no documentation for specific sites in the study area. From a review of technical papers on this subject, it is generally true that soil/leachate interactions are not a severe problem at domestic waste sites. However, adverse affects on clayey soils upon exposure to some waste streams have been documented in the literature. For example, exposure of clay soils to some organic chemicals leads to increases in hydraulic conductivity by one to three orders of magnitude (Anderson and Brown, 1981). Changes in hydraulic conductivity are thought to be due to shinkage of the diffuse layer around individual soil particles with varying dielectric constants for each solute leading to a larger area for flow of interstitial fluids. Exposure of clayey soils to some organics results in a change in structure of the soil surface from massive to blocky with visible pores and cracks (Brown and Anderson, 1983). Reactions of this nature seem to be more pronounced for some combinations of soil and chemicals than for others.

Additional groups of chemicals exist which are also somewhat incompatable with clayey soils although this information is again not specific to the sites in the study area. For instance, Folkes (1982) reported that exposure to acids and bases may result in an increased hydraulic conductivity due to dissolution of the soils as well as shrinkage of the soil particle diffuse layer in the presence of high cation concentrations. Stewart (1978) reported poor performance of compacted clays in the presence of caustic petroleum sludge, steel-pickling waste and electroplating sludge. As a consequence, there is a need to assess the compatability of the individual wastes disposed at a site with the natural geologic material present. In some cases, waste streams from specific processes or waste generators may require an alternate method of disposal in order to protect the integrity of the waste disposal system. In this case, there are a number of different approaches which may be adopted, such as synthetic membrane liners or asphalt-emulsion barriers, which are discussed further in Section 2.8.2.

In terms of different but currently in use waste disposal methodologies, there are a number that have been adopted at various sites in the study area. For instance, the Tricil site at Corunna proposes to utilize a natural attenuation approach similar to that just described but differs in that all wastes are placed within the unweathered zone at depths of 6 to 18 meters. Within the weathered zone, from 0 to 6 meters in depth, the excavation is filled with compacted clay till derived from the original excavation. In this manner, the potential for solute transport and free phase flow along fissures is eliminated and the length of the diffusive transport path to the land surface is increased leading to longer diffusive travel times to the biosphere. Potential problems with this methodology arise in that wastes are placed

deeper in the clay till stratigraphic unit, at a location closer to the fresh water aquifer. Hydraulic gradients in the vertical sense are downward over most of the area. Downward advection combined with diffusive transport will result in shorter travel times to the fresh water aquifer relative to waste disposal at shallower depths.

Dow Chemical Canada Incorporated, at their LaSalle Road plant, has utilized a steel sheet pile wall in order to assist in management of leachate generated from waste disposal activities on their property. The sheet pile wall is installed between the site and a township ditch where leachate has been observed and collected for subsequent treatment. Unfortunately, for this particular sheet pile wall, no performance data is available which documents its performance or its impact on ground water quality. However, a number of inferences are possible regarding the performance of sheet pile walls in general.

From information available at the Ministry office regarding the Dow site, it appears that the sheet pile wall completely encloses the site. The result of installing a sheet pile wall which encloses the site is that ground water levels on the upgradient side (or inside) of the wall will rise due to infiltration as no outlet is available. This will eventually lead to increased flow of ground water below the wall as a result of the higher hydraulic gradients. Thus, a sheet pile wall of this nature simply lengthens the ground water flow path and results in a higher water table within the enclosed area. In addition, it is difficult to construct a sheet pile wall which does not leak at the joints. Thus, sheet pile walls are often of limited use in ground water contamination problems, even to create a longer flow path.

Another consideration which arises with the use of sheet walls is that they are often made of cold rolled steel which readily corrodes upon exposure to dilute acids and brines.

2.8.2 Alternate Waste Containment Methodologies

A large number of waste dispoal methodologies exist which are implemented at either the construction stage or the post-operation stage and are applicable to varying degrees in the area under study. As a large number of alternative waste disposal techniques do exist, it was considered of greatest interest to discuss primarily the methodologies perceived to be most applicable to the problems encountered in the study area. This approach was adopted in developing the following discussion.

The current methodologies for waste containment within the study area and their inherent problems were discussed in Section 2.8.1. The main problems identified with the use of the native clayey soils, as is done throughout the study area, can be summarized as follows:

- migration in fissures and fractures;
- ineffective capping;
- diffusion to the biosphere;
- diffisuion and convection to the fresh water aquifer;
- interaction between the soil and the waste.

Migration of solutes and waste liquids in the fissures and fractures is a problem associated with waste disposal activities in the weathered zone. In the situation where wastes are placed in an excavation in the weathered zone, they are in direct contact with the fissures/fractures which likely leads to more rapid transport through the ground water system.

To alleviate the enhanced contaminant transport through these fissures, it is necessary to provide a degree of isolation of wastes from the surrounding soil. To accomplish this objective, a liner such as a synthetic membrane, a soil admix (i.e., soil-cement, soil bentonite) or a more uniform soil (i.e., compacted clay) may be utilized. Alternatively, a vertical barrier, such as a slurry trench or grout curtain may be placed around the perimeter of the site, extending to the unweathered zone at depth, which provides a low hydraulic conductivity zone and will act to further inhibit waste migration.

When the wastes are placed in the unweathered zone, fissures/fractures are less of a problem as they are not in direct contact with the waste. However, diffusion of solutes up into the weathered zone surrounding the waste site cap may occur due to concentration gradients. Efforts to alleviate this problem include similar measures to those just discussed for waste placement in the weathered zone.

The implications resulting from ineffective capping of a waste site are discussed in Section 2.8.1 and generally result in mounding of the water table leading to higher contaminant transport rates from the waste site. If it is perceived that the hydraulic properties of a cap are less than that of the surrounding stratigraphy, then several alternatives are available to enhance the cap performance. One possibility includes utilizing a synthetic membrane within the cap to further inhibit infiltration. A sloping synthetic membrane, in conjunction with a cap which is built above and sloped at a higher gradient then the surrounding grade, will reduce infiltration and subsequent mounding in the water table while promoting run-off of precipitation. Alternatively or

conjunctively, the clay cap could be compacted to a greater degree when placed above the waste, thus enhancing its performance.

Diffusion to the biosphere is a problem which is most significant when conditions of a high water table and shallow placement of wastes prevail jointly. Remedial alternatives include artificially lowering the water table using an engineering system such as drainage tiles which will also serve to collect contaminated ground water. However, this is difficult due to technical and economical considerations. For example, the low transmissivity of the clayey tills leads to small area of influence of any type of drain or well system. As a result, utilization of, say, a tile drain system would involve placing tiles at close intervals which is very costly.

In situations where the wastes are placed fairly shallow, a tangible solution exists to address diffusion to the biosphere if there is a thick layer of low hydraulic conductivity soils below the site. This scheme involves selecting a capping material which will allow infiltration to the saturated zone at a rate which is equivalent to the upwards rate of diffusion. In this way, upward diffusion from the waste is effectively stagnated. However, the advective transport rates of contaminants below the site is likely to increase with this scheme such that it is imperative to have a thick sequence of desirable soils (i.e., low hydraulic conductivity) below the site.

Alternatively, a synthetic membrane liner may be utilized in the surface cap to inhibit infiltration and likely increase the thickness of the unsaturated zone thus significantly slowing the upward diffusive transport rate to the land surface.

However, the upward diffusive rate of migration throughout the saturated zone will likely remain unchanged. Further migration is likely to occur in the horizontal orientation in a direction away from the site. Release of contaminants to the biosphere is also possible by uptake through plant roots and volatilization into the unsaturated zone.

Transport of contaminated ground water to the fresh water aquifer, by both advection and diffusion, is most significant when the thickness of the clayey till below the waste is relatively small. However, in general, it is not considered to be a great threat to environmental conditions. Possibilities for reducing the adverse impacts of the waste disposal site include reducing the advective component of transport by reducing the hydraulic gradient towards the fresh water aquifer. This could be accomplished by lowering the liquid levels in the waste disposal excavation to a level equivalent to or lower than the piezometric elevation in the fresh water aquifer. In this way, advection could possibly be reduced such that advection opposes diffusion with the net effect being reduction in solute transport rates. Although this is difficult in the low hydraulic conductivity soils present, it may be feasible at some sites through utilizing a combination of gravel filled trenches, drain tiles and wet wells around the perimeter of the waste disposal trenches.

Reducing the downward diffusive flux may be achieved by utilizing a liner as discussed previously with respect to reducing transport through fractures and fissures at the base of the site. The liner will likely inhibit diffusion to a greater degree than the native soils.

Interaction of chemicals originating from the waste with the native soils present at the site is a problem with specific chemical and soil combinations as identified in Section 2.8.1. In order to address this problem, it is first necessary at the design stage to acquire an understanding of the waste types and their chemical composition for which the site is to be used. Numerous studies in the literature document the behaviour of various groups of chemicals with specific soils (Stewart, 1978; JRB, 1984; Haxo, 1981; D'Appolonia, 1981; Anderson et al., 1984; Anderson and Brown, 1984; Anderson, 1983). In this manner, potential problems can be identified and addressed at the preliminary stages and incompatible waste types can either be accommodated through a modified containment system or transported elsewhere.

During the operation stage, various wastes delivered to a site should be checked against the possible adverse reactions which may occur. In addition, unfamiliar waste types may need to be tested in the laboratory to ensure compatibility with the waste containment system components as well as the other chemicals present. In this manner, the integrity of the waste containment system can be preserved.

3.0 WASTE DISPOSAL SITES INVENTORY

3.1 Lambton County

Within Lambton County, thirty-one (31) waste disposal sites were examined. Available information from MOE files, consultants reports and published reports were examined and tabulated. Tables which correspond to the section numbers summarize the available information and characterize each individual disposal site.

3.1.1 Site No. L-1. Dow Chemical of Canada Ltd. (Scott Road)

The Dow Chemical of Canada Ltd. waste disposal site off Scott Road in Sarnia (part Lots 10 & 11 Range 3, RP 122 Scott Road) serves the nearby Dow manufacturing facilities. The site has been in operation since 1948. Disposal operations consist of controlled landfilling and clay capping of hazardous and non-hazardous solid and liquid wastes that originate from the production of vinyl chloride. Included are various oily sludges and solvents containing chlorinated hydrocarbons, specifically hexachlorobutadiene. Also, contaminated soils and equipment from around the production facilities have been transported to the waste disposal site. Approximately 1,000 tonnes of waste (28% non-hazardous, 26% liquid and 46% hazardous waste, MOE 1984c) are received annually.

The site, approximately 4 hectares in area, is situated on a thick clay till deposit extending more than 30 m to the underlying bedrock of Kettle Point shale. Surface and ground water monitoring systems have been in place since 1980 as well as a leachate control system. Additional ground water monitoring wells were installed in 1982. The leachate control system consists of a collection/holding ditch along the north

Table 3.1.1. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-1
Registration Area: Sarnia,
Site Certificate Number: A030104
Certificate Holder: Dow Chemical of Canada Ltd.
Location: City of Sarnia, UTM 386200E, 4755600N

Sources of Information: MOE Approval file, OH Materials Co. (1984)

	Description
Wastes Produced or Received at Site	
Location of waste production	off disposal site at Dow facilities
Location of waste disposal	controlled placement throughout 4 hectare site
Waste characterization	oily sludges and solvents containing chlorinated hydrocarbons, contaminated soil, others
Quantities disposed of	1,000 tons solid waste per year, liquid disposal rates not available
Period of operation	1948 to present, closure plan being developed by company
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling with clay capping of older portions
Surface runoff control	perimeter ditch, separation of contaminated and uncontaminated runoff, monitoring of off-site releases
Leachate collection system	sheet steel pile wall (4-5 m deep) to prevent off-site transport, surface runoff and leachate collection ditch
On-site treatment facilities	carbon treatment of surface runoff and leachate
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - via Scott Road ditch
Potential for flooding	none
Potential for surface runoff	north to township ditch and south to adjacent Fiberglass Canada site
Nearest receiving waters	township ditch adjacent to site

Table 3.1.1a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	
Surficial geologic deposits	clay till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	ground water study by OH Materials Co. (1984) but not publicly available
Details of shallow ground water flow	unavailable
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface (2)
Relationship of waste to flow systems	waste leachate likely recharges local watertable
Site Geochemistry	
Natural ground water quality characterization	site geochemistry has been studied by Dow but is not publicly available
Leachate quality characterization	
Shallow ground water quality on-site	
Deeper ground water quality on-site	
Attenuation characteristics of on-site deposits	
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and subsurface migration
Current evidence of leachate migration	previous contaminated runoff and sediments found in surface ditches off-site, although not conclusively attributable to DOW based on O.H. Material Study (1984)
Adequacy of surface water quality monitoring	continuous or batch surface water monitoring may be acceptable provided water quality parameters appropriate
Adequacy of ground water quality monitoring	inadequate

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

boundary of the site. The contents of the ditch are treated via activated carbon beds then released to the Scott Road ditch which drains to the Township Ditch. In addition, a steel sheet pile wall has been installed around the full perimeter of the site to a depth of 4 to 5 m below grade to control any off-site leachate migration. However, the effectiveness of the sheet pile wall to contain off-site ground water flow has not been demonstrated. Surface run-off is the most likely pathway for leachate movement off-site.

The adequacy of the existing leachate collection system and surface run-off controls to prevent off-site migration of contamination from this site have not been proven. Surface run-off is not properly contained and may be migrating southerly towards the adjacent Fiberglass Canada site. Ground water mounding within the landfill is likely to create a large hydraulic gradient across the sheet pile wall resulting in short circuiting of the wall and increased off-site ground water flow. The present monitoring program is inadequate and needs to be improved. Dow has also found and removed contaminants from the Township Ditch.

3.1.2 Site No. L-2. Esso Petroleum Canada

Esso Petroleum Canada operates a landfill for non-hazardous refinery wastes and construction debris near Scott Road in Sarnia.

The site is located in Range 3 Lots 8 and 9 of Lambton County. The Esso site is registered under Certificate of Approval number A030105 and in 1985 received about 4,000 tonnes of non-hazardous refinery coke and spent catalysts and 57,000 tonnes of construction and demolition debris. The site is situated on the regional clay-till plain. Hydrogeologic

Table 3.1.2. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: L-2
Registration Area: Sarnia
Site Certificate Number: A030105
Certificate Holder: Esso Petroleum Canada, Sarnia
Location: City of Sarnia UTM 386250E, 4754900N

Sources of Information: MOE Approval files

	Description
Wastes Produced or Received at Site	
Location of waste production	off disposal site at Esso refinery
Location of waste disposal	throughout 24 hectare site
Waste characterization	80 % construction debris, 20 % spent catalysts and fluid coke
Quantities disposed of	61,000 tonnes per year (1985)
Period of operation	1954 - present, future use of 15 years expected
Waste Containment Facilities	
Method of containment/disposal	landfilling
Surface runoff control	berm around southwest corner
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Scott Road ditch
Potential for flooding	none
Potential for surface runoff	moderate
Nearest receiving waters	ditch to the east and township ditch to the west

Table 3.1.2a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	thin glaciolacustrine sands overlying thick clay till
Thickness of overburden	30 + metres
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	no site specific studies available
Details of shallow ground water flow	not documented, limited southwesterly flow documented on adjacent Polysar site
Details of deeper ground water flow	westerly flow in regional aquifer at bedrock surface (2)
Relationship of waste to flow systems	waste leachates recharge local watertable
Site Geochemistry	
Natural ground water quality characterization	none
Leachate quality characterization	none
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high due to low permeability (ref: similar deposits at adjacent Polysar)
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff to east ditch to township ditch
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect, acceptable in light of reported waste composition
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

investigations available for the nearby Polysar Limited landfill area suggest that the tills have hydraulic conductivities in the order of 10^{-8} cm/sec. It is likely that the shallow ground water movement on-site is radially outwards from the site at very limited rates. A berm has been constructed on the southwest corner of the site and site drainage is generally to the east of the township ditch. Neither ground water or surface water monitoring is currently conducted on-site because the site contains innocuous wastes.

3.1.3 Site No. L-3. Polysar Limited

The Polysar Limited disposal site off Scott Road in Sarnia serves the nearby Polysar manufacturing facilities. The site has been in operation since 1942 and consists of industrial waste and flyash areas. Disposal operations consist of controlled landfilling of various inert sludges, plastic resins and alkali, inorganic and rubber wastes over an area of approximately 11 hectares. At present, approximately 25,000 cubic metres of liquid wastes (MOE, 1984c) are received per year. Landfilling is accompanied by capping of wastes with fly ash or imported clay and silty clay material. Surface run-off and waste leachates are directed into surface storage lagoons where monitoring and treatment is required. Monitored parameters include pH, total organic carbon, phenols, copper and ammonia. Off-site release of surface waters has ceased, and all surface waters are now treated at the companies' Biox treatment plant.

Shallow preliminary hydrogeologic investigations were completed on-site by Dominion Soil Investigations Inc. in 1984. Borehole logging and piezometer installation were completed in these investigations. Five piezometer nests of two piezometers each were located and installed at the corners and center of the

Table 3.1.3. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-3
Registration Area: Sarnia
Site Certificate Number: A030107
Certificate Holder: Polysar Limited, Sarnia
Location: City of Sarnia UTM 386620E, 4755550N

Sources of Information: MOE Approval files, Dominion Soil Investigation Inc. (1984)

	Description
Wastes Produced or Received at Site	
Location of waste production	off disposal site at Polysar facilities
Location of waste disposal	industrial landfill area of 11 hectares, fly ash storage area of 15 hectares
Waste characterization	inert sludges, plastic resins, alkali and inorganics, rubber wastes, others, poor waste inventory
Quantities disposed of	19,075 tons solids per year, 25,000 cu. m. per year
Period of operation	1942 to present, future use of 20 years expected
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling and capping with clay or fly ash, separate lagoons
Surface runoff control	waste leachates directed into lagoons, transferred to Polysar's Biox treatment plant by pipeline
Leachate collection system	none
On-site treatment facilities	as above
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Scott Road ditch
Potential for flooding	high in area of industrial landfill
Potential for surface runoff	none with existing controls
Nearest receiving waters	township ditch

Table 3.1.3a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	3 to 6 metres of oxidized till or fill overlying gray till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	5 boreholes/piezometer installations to max depth of 14 m, insitu permeability testing, ground water and surface water sampling but generally a poor study
Details of shallow ground water flow	locally southwesterly flow at less than 10 cm/year (till permeabilities less than 3 x 10^{-7} cm/sec), radial flow from industrial waste area
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	waste leachates and lagoons recharge local watertable, watertable mounding in waste
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	occasional monitoring for TOC, pH, phenols, copper, ammonia
Shallow ground water quality on-site	site investigation indicates elevated DOC and phenols to north of landfill
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	leachate springs at berm
Adequacy of surface water quality monitoring	acceptable sampling procedure, water quality parameters should be revised
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

site. The studies indicate that several meters of fill and wastes overlie more than 10 meters of silty clay till. On-site, however, portions of the landfill apparently rise over 8 m above ground. (MOE site inspection report, 1983). The measured hydraulic conductivities of the tills vary from 8×10^{-8} cm/sec to 3×10^{-7} cm/sec and greatly restrict ground water movement on the site. Using the measured water table gradient of 0.01 m/m and an assumed porosity of 0.1 in the weathered surficial till, the shallow ground water movement on site is in the order of 10 cm/yr. Shallow lateral movement is apparently directed outwards from the landfill and may eventually discharge into perimeter ditches or be lost as evapotranspiration. The data collected suggests that vertical ground water movement on-site is downward (for four of the five piezometer nests, water levels in the deep piezometer were lower than the shallow piezometer confirming that the hydraulic gradient is downward). Downward movement towards a deep aquifer at the bedrock surface is consistent with the general regional hydrogeology.

Ground water quality monitoring was subsequently conducted in the set of deeper piezometers installed from 9.6 to 14.2 metres below ground. The ground water quality in two piezometers, one located to the northeast of the landfill and another to the northwest but adjacent to one of the lagoons, had elevated dissolved organic carbon levels and phenols. These results should be confirmed by analysis of further samples. The ground water quality along the downgradient perimeter of the site (tens of metres beyond the landfill or lagoons) showed no evidence of possible quality changes due to the operation of the site.

In general, ground water monitoring at this site is inadequate to determine whether or not contamination is leaving the site. Leachate springs have been noted by MOE officials on the east berm surrounding the industrial waste landfill. Containment of surface run-off, especially on the east side of the industrial waste landfill is inadequate.

3.1.4. Site No. L-4. Town of Petrolia

The Town of Petrolia is licensed to fill 26 hectares of a 41 hectare site located at the extreme southeast corner of the town boundary - Lot 16, Concession 10. The site, used for waste disposal since 1948 and licensed (A030303) since 1971, serves the Town of Petrolia, Village of Oil Springs, Village of Oil City, Village of Wyoming, Township of Enniskillen and the Township of Plympton along with several industries (Globe Asphalt Products, Detroit Gasket and Plant National Ltd.) in the area. The waste is predominantly domestic (68%), with some commercial (20%), non-hazardous industrial (10%), and bulk waste and brush (2%). 6,900 tonnes are disposed in total per year using a ramp-type landfilling operation.

Conestoga-Rovers and Associates (CRA) completed a hydrogeologic investigation in 1980. Within the disposal area, there is an 11 to 24 meter layer of overburden overlying the bedrock. The soils are predominantly clays (45%) and silts (44%) with some sand (9%) and minor amounts of gravel (2%). The surface topography varies from a high elevation of approximately 200 meters a.s.l. to a low elevation of approximately 190 meters a.s.l. Surface drainage is towards a drainage ditch through the center of the site which flows into a tributary of Bear Creek. Adjacent to the drainage ditch fairly steep slopes are encountered, however, the remainder of the site is relatively flat.

Table 3.1.4. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenfication # L-4
Registration Area: Sarnia
Site Certificate Number: A030303
Certificate Holder: Petrolia, Town of
Location: Town of Petrolia UTM 408490E 4747000N

Sources of Information: MOE Approval File,
Conestoga-Rovers & Assoc., (1980)

	Description
Wastes Produced or Received at Site	
Location of waste production	Local municipalities and industry
Location of waste disposal	26 hectares within a 41 hectare site
Waste characterization	domestic and commercial, non-hazardous, white goods, brush
Quantities disposed of	6,900 tonnes per year
Period of operation	1971 to present, estimated life 50 years
Waste Containment Facilities	
Method of containment/disposal	landfill with soil cover
Surface runoff control	surface water runoff is directed to sedimentation pond
Leachate collection system	perimeter collection system under construction
On-site treatment facilities	collected leachate to sewage treatment plant
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Sydenham River - Bear Creek
Potential for flooding	moderate
Potential for surface runoff	moderate to low with sedimentation pond
Nearest receiving waters	Tributary of Bear Creek

Table 3.1.4a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	24 meters
Underlying bedrock deposits	Hamilton Formation limestone - shale
Site Hydrogeology	
Extent of investigations	4 piezometers installed, permeability testing, gas monitoring, ground water and surface water monitoring.
Details of shallow ground water flow	locally following relief south west to creek (till permeability 8×10^{-9} cm/sec)
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	high conductivity, SO_4, $CaCO_3$
Leachate quality characterization	none
Shallow ground water quality on-site	high conductivity, SO_4 and $CaCO_3$
Deeper ground water quality on-site	none
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	no evidence of leachate migration
Adequacy of surface water quality monitoring	monitoring in effect
Adequacy of ground water quality monitoring	monitoring in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Standpipes and observation wells were installed to determine the local ground water conditions. It was determined that the local ground water table was generally 0.6 to 1 meter below the ground surface, flowing in the direction of primary surface relief towards local ditches and streams. The deep ground water system, which is the main water supply aquifer, is believed to flow in a westerly direction.

Ground water and surface water samples were taken to determine if contaminants were migrating off site. The tests failed to identify any migrating pollutants. However, potential migration of leachate off site would most likely be by surface run-off.

As a result of the CRA (1980) study, the landfill has been improved with additional surface water and ground water monitoring. A sedimentation pond collects surface water run-off and a perimeter collection system is being installed. Collected leachate will go to a sewage treatment plant for disposal.

3.1.5 Site No. L-5. Canflow Services

The Canflow Services disposal site is located north of Petrolia in lots 35 to 49 inclusive. The site has been in operation since 1983 and currently operates under Certificate of Approval number A030330. The wastes disposed of consist of 800 tonnes per year of solid waste of which 50% is non-hazardous industrial and the remaining is construction and demolition debris and 800 cubic meters per year of liquid wastes, composed principally of alkalis and inert sludges. The 9 hectare site accepts waste from local industries including Polysar, Sunoco, Shell and CIL.

Table 3.1.5. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-5
Registration Area: Sarnia
Site Certificate Number: A030330
Certificate Holder: Canflow Services
Location: Town of Petrolia, UTM 406500E 4750100N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	local industries
Location of waste disposal	9.0 hectare site
Waste characterization	non-hazardous solid, construction and demolition debris, liquid sludges
Quantities disposed of	800 tonnes per year solid, 800 m^3 per year liquid
Period of Operation	1983 to present
Waste Containment Facilities	
Method of containment/disposal	no containment
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Sydenham River - Stonehouse Drain
Potential for flooding	moderate
Potential for surface runoff	moderate
Nearest receiving waters	Buttermilk Creek/Bear Creek

Table 3.1.5a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glaciolacustrine clay overlying clay till
Thickness of overburden	30 meters
Underlying bedrock deposits	Hamilton Formation limestone-shale
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	westerly regional flow at bedrock surface
Details of deeper ground water flow	westerly regional flow
Relationship of waste to flow systems	not documented
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	domestic wells in the area monitored by MDE
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	in effect but adequacy unknown
Adequacy of ground water quality monitoring	none in effect however domestic wells in the area are monitored by MDE

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Currently no systems for the containment or control of leachate are in place. A berm has been constructed on the south-east side of the site to control surface run-off. Surface water monitoring is being conducted however the exact extent is not documented. No shallow ground water monitoring is being done at present, however the Ministry has been monitoring several domestic wells in the area for 15 years with no indication of contamination of the fresh water squifer.

The site is situated in a clay till plain as described by Chapman and Putnam (1984) with the surficial deposits being glaciolacustrine clays overlying the clay till. Depths to bedrock of approximately 30 meters (100 feet) can be expected in the area. The most likely pathway for leachate movement off-site would be by surface flow.

3.1.6 Site No. L-6. Township of Dawn

The Township of Dawn has operated a 14 hectare site on the east half of Lot 21, Concession 5 from 1972 to present (Certificate of Approval number A031502). The site accepts domestic waste and some agricultural waste, fence and wire scrap from residents within the township. At present, approximately 80 tonnes of refuse are landfilled annually. No surface water, leachate control or containment facilities are in place at the site and no surface water or ground water monitoring is presently being undertaken.

The site is located on approximately 20 meters of clay till overlying the Kettle Point shales. The most likely path for leachate movement off-site would be by surface flow.

Table 3.1.6. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-6
Registration Area: Sarnia
Site Certificate Number: A031502
Certificate Holder: Dawn Twp.
Location: Township of Dawn UTM 404680E 4726350N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Dawn Twp.
Location of waste disposal	12 hectares within 14 hectare site
Waste characterization	Domestic, agriculture waste, fence, wire, scrap
Quantities disposed of	80 tonnes per year
Period of operation	1972 to present, estimated life 20 years
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Sydenham River - Booth Creek
Potential for flooding	low
Potential for surface runoff	moderate
Nearest receiving waters	drainage ditch to Booth Creek or Molly Creek

Table 3.1.6a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	20 meters
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	none
Details of shallow ground water flow	not documented
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow surface
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.1.7 Site No. L-7. P & E Oil Recyclers

The P & E Oil Recyclers site is situated on the east half of Lot 12, Concession 12 in the Township of Enniskillen. The site stores used oil in underground tanks and disposes of oil field brines in two deep disposal wells. In 1982 50 m^3 (10000 gallons) of waste were accepted at the site. The major industries served are Dome Petroleum, Imperial Oil, Polysar Ltd. and Uniroyal. The site has existed since the late 1800's and has been licensed since 1971 (Certificate of Approvals number A031602). The site is located in a clay till overlying the Hamilton Formation shales and limestones. The approximate thickness of the overburden is 30 meters. No surface water or ground water monitoring programs are in effect.

The site was developed in the latter part of the nineteenth century by the Canadian Oil Company for the subsurface storage of crude oil in underground cedar lined tanks. The tanks were excavated in heavy clay soil to depths ranging from 4 meters (13 feet) to 18 meters (60 feet) below grade.

In 1965 and 1969, two deep disposal wells were drilled into the Detroit River group and were used for the disposal of liquid industrial wastes until 1984 when the Ontario Ministry of the Environment regulated against the disposal of industrial wastes, except for oil field brine, in this fashion. This regulation led to the storage of industrial wastes in the forenamed subsurface storage tanks.

In 1979, as re-refined used oil became increasingly marketable, the site owner expanded into the oil recycling and reclamation business. This led to MOE approval for an onsite oil recovery

Table 3.1.7. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-7
Registration Area: Sarnia
Site Certificate Number: A031602
Certificate Holder: P & E Oil Recyclers
Location: Township of Enniskillen UTM 406340E, 4749600N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	local industries
Location of waste disposal	1.0 hectare on 1.37 hectare site
Waste characterization	used oil
Quantities disposed of	50 m^3 per year
Period of operation	1971 to present (site in existence since 1900's)
Waste Containment Facilities	
Method of containment/disposal	underground cedar lined storage tanks
Surface runoff control	none (berm partially completed)
Leachate collection system	none
On-site treatment facilities	oil recovery unit, used as required
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Sydenham River - Bear Creek
Potential for flooding	moderate
Potential for surface runoff	high, MOE recommended construction of earthen clay berm to contain potential off site migration
Nearest receiving waters	Buttermilk Creek/Bear Creek

Table 3.1.7a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	30 meters
Underlying bedrock deposits	Hamilton Formation shale - limestone
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	south easterly to Bear Creek
Details of deeper ground water flow	westerly flow of regional aquifer at bedrock surface
Relationship of waste to flow systems	stored waste likely in contact with ground water
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	waste analysed by MOE
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface flow to ditch, subsurface flow
Current evidence of leachate migration	oils found in ditch adjacent to site on numerous occasions
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

unit and the onsite disposal of oil reclamation solids. With this, waste hauling and storage ceased. Oil field brine continues to be injected into the deep wells.

The underground storage tanks have capacity to hold over 13,650 m^3 (3,000,000 imp. gallons) and the last documented reports (MOE files) indicate that all of the tanks are full. The liquid contents of the tanks were sampled and analyzed in November 1983 by the MOE. The results indicate that the tanks contain oil, brine, water, caustic and/or acidic compounds, phenolic compounds, mineral salts and heavy metals including lead and chromium. The potential for off-site migration exists and has been documented. An oily black liquid was observed in the drainage ditch due west and adjacent to the P & E property on several occasions by MOE personnel. At present there is virtually no onsite containment for the off-site migration. In addition, many of the tanks are uncovered, or those that are covered, have weak and rotten wooden covers, therefore allowing infiltration of precipitation which potentially can cause overflows of the contents.

The Ministry of the Environment imposed a control order on the site directing the owner to undertake certain actions to conform with the Environmental Protection Act. The recommended control order required that 1) all off-site migration of spillage outside the perimeter of the site along with any contaminated soil must be removed and disposed of at an approved disposal site; 2) a three foot high compacted earthen clay berm be constructed on the site perimeter to contain potential off site migration and 3) that a secure cover or roof capable of preventing the release of odorous emissions be constructed for all subsurface tanks. Requirements 1) and 3) were to be completed by the present and requirement 2) is to be completed by May 1986.

3.1.8 Site No. L-8. Dow Chemical of Canada Ltd. (Lasalle Road)

Dow Chemical operates an industrial waste disposal site near LaSalle Road in Sarnia under Certificate of Approval number A031801. The site is approximately 20 ha in size and accepts 22,800 tonnes of solid waste and 8,900 m^3 of liquid waste per year. The wastes include latex solids, graphite, glycol filter cake, alkali sludges, biox sludges, plant and animals wastes and some hazardous wastes. The waste is characterized at 32% non-hazardous, 28% liquid and 40% hazardous. The operation consists of controlled landfilling with clay capping. Construction of berms, perimeter ditches and a run-off pond have been proposed. A hydrogeologic study was conducted by Dominion Soil Investigation (1983). Five (5) borehole/ piezometers were installed to a maximum depth of 10 meters. Local ground water flow was determined to be northward towards Talfourd Creek at less than one centimeter per year. The local surficial soils were determined to be a low plasticity silty clay that is relatively uniform in nature. The top 6 meters were fractured. Till permeabilities of the order of 10^{-7} cm/sec with variations of approximately one order of magnitude for the clay with or without fractures were established.

No ground water quality data was available and it is not known at present if any monitoring is being done. Existing documentation suggests that monitoring systems for surface water and ground water are proposed. The most likely pathway for leachate migration movement off-site would be via surface run-off and shallow ground water flow. Problems with surface run-off of lime sludges to adjacent CN property have occurred in the past. Recent construction of perimeter ditches and a surface water containment pond has eliminated any potential

Table 3.1.8. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-8
Registration Area: Sarnia
Site Certificate Number: A031801
Certificate Holder: Dow Chemical Canada Inc, Sarnia
Location: Township of Moore, UTM 384100E, 4751200N

Sources of Information: MOE Approval Files, Dominion Soil Investigation Inc (1983)

	Description
Wastes Produced or Received at Site	
Location of waste production	off disposal site at Dow manufacturing facilities
Location of waste disposal	16 hectares within 20 hectare site
Waste characterization	latex solids, graphite, glycol filter cake, alkali sludges, bi-ox sludges, others
Quantities disposed of	22,800 tonnes of solid per year, 8,900 cu. m. of liquid per year
Period of operation	1960 to present, future use of 20 years expected
Waste Containment Facilities	
Method of containment/disposal	controlled landfill with clay capping, runoff pond and berms proposed
Surface runoff control	surface water containment pond proposed
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	low
Potential for surface runoff	none if proposed berms and recommended perimeter ditches completed
Nearest receiving waters	Talfourd Creek

Table 3.1.8a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	4m of brown oxidized till overlying gray massive till, fractures present to 6 m
Thickness of overburden	35+ metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	5 borehole/piezometer installations to max depth of 10 m, insitu permeability testing
Details of shallow ground water flow	local northward flow towards creek at less than 1 cm/year (till permeabilities less than 4 x 10^{-7} cm/sec)
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	ground water mounding in waste, recharges local watertable
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	none
Shallow ground water quality on-site	not documented, internal Dow results may be available
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	system proposed for future runoff collection pond, runoff analysed before discharge monitored by District office
Adequacy of ground water quality monitoring	system proposed but present piezometer network inadequate

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

off-site contaminant migration. Considering the contamination potential of the waste disposed on-site the construction of the proposed monitoring systems is imperative.

3.1.9 Site No. L-9. Ontario Hydro-Courtright

The Lambton Generating Station is a coal-fired plant operated by Ontario Hydro near the town of Courtright. The plant annually produces about 280,000 tons of coal ash which is locally landfilled on site. The landfill is registered under Certificate of Approval number A031802. The plant site extends eastward 1 1/2 km from the St. Clair River with the western edge of the 43 hectare landfill located about 0.6 km from the river. Topographic relief on-site is minimal but locally directs surficial drainage towards the river or into Bowens Creek which discharges into the river approximately 2 km south of the plant. The site is underlain by over 40 m of silty clay till which typical ranges from 50 to 60% in clay content (Hanna, 1966; Desaulniers, 1982). Detailed on-site studies at two locations by Desaulniers (1982) indicates that the hydraulic conductivity of the tills is very low ranging from 0.5 to 15 x 10^{-8} cm/sec. Overall horizontal movement of shallow ground waters is directed towards the river at rates from centimeters per year to meters per year depending upon the extent and characterization of weathering of the tills. Rates of downward movement are in the order of centimeters per year.

Bottom ash from the plant is initially slurried into a settling pond but is regularly transferred to the main fly ash landfill. The landfill is an above-ground operation. Drainageways around the landfill collect run-off for pH adjustment and monitoring. General plant site drainage is controlled by perimeter ditches. Ground water monitoring is not conducted.

Table 3.1.9. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-9
Registration Area: Sarnia
Site Certificate Number: A031802
Certificate Holder: Ontario Hydro, Courtright
Location: Township of Moore, UTM 380930E, 4739460N

Sources of Information: MOE Approval Files, Hanna (1966)
Desaulniers (1982)

	Description
Wastes Produced or Received at Site	
Location of waste production	Ontario Hydro - Lambton Generating Station
Location of waste disposal	43 hectares to northeast of generating station
Waste characterization	flyash and bottom ash (70/30)
Quantities disposed of	280,000 tonnes per year
Period of operation	1969 to present, future use of 15 years expected
Waste Containment Facilities	
Method of containment/disposal	landfilling, bottom ash initially enters settling pond and is removed regularly
Surface runoff control	runoff from landfill collected for pH adjustment, perimeter ditch on property
Leachate collection system	none
On-site treatment facilities	as above
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River
Potential for flooding	none
Potential for surface runoff	none
Nearest receiving waters	St. Clair River and Bowen's Creek

Table 3.1.9a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	45+ m
Underlying bedrock deposits	Port Lambton shale or sandstone
Site Hydrogeology	
Extent of investigations	geotechnical studies for construction purposes, research studies on hydrogeology
Details of shallow ground water flow	not documented
Details of deeper ground water flow	westerly regional flow in bedrock aquifer
Relationship of waste to flow systems	ash leachates recharge local water table
Site Geochemistry	
Natural ground water quality characterization	high major ion concentrations, Desaulnier (1982)
Leachate quality characterization	not documented
Shallow ground water quality on-site	detail study by Desaulniers (1982)
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.1.10 Site No. L-10. Tricil

The Tricil Limited waste disposal site is located in Lot 9, Concession 10 in the Township of Moore about 12 km southeast of Sarnia. The site has been in operation since 1962 and currently operates under Certificate of Approval number A031806. Approximately 20,000 m^3 of liquid industrial waste and 86,000 tons of solid waste are received per year. Liquids are generally incinerated on-site but if unsuitable, are mixed with fly ash and placed in a controlled solid wastes landfill. Waste treatment and disposal operations occupy approximately 28 hectares. An application has been made to expand the site.

The site is underlain by over 40 meters of silty clay till of relatively very low hydraulic conductivity. A regional aquifer exists beneath the till at the bedrock surface. An extensive three-dimensional ground water monitoring network is in place on-site within the till and underlying aquifer.

The hydraulic conductivity of the tills from field and laboratory measurements was found to be less than 10^{-10} m/sec and downward ground water movement estimated to be less than a centimeter per year (Hydrology Consultants Limited, 1984). Shallow radial ground water movement from the site is possible through the upper weathered portion of the till but current monitoring demonstrates that this movement is very limited.

It is estimated that ground water movement from surface to the deep aquifer would take 40,000 years or more. Migration of contaminants by chemical diffusion, however, could take considerably less time. Ground water movement within the aquifer is locally towards the northeast, away from the St. Clair River.

Table 3.1.10. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: L-10
Registration Area: Sarnia
Site Certificate Number: A031806
Certificate Holder: Tricil Limited, Mississauga
Location: Township of Moore, UTM 393770E, 4747570N

Sources of Information: MOE Approval Files, Hydrology Consultants (1984), Giffels and Associates (1974)

	Description
Wastes Produced or Received at Site	
Location of waste production	industrial wastes from throughout Southern Ontario
Location of waste disposal	central 28 hectares of 42 hectare site
Waste characterization	81% non-hazardous, 10% liquid, 9% hazardous, acids, caustics, sludges
Quantities disposed of	85,500 tonnes of solids per year, 20,250 cubic metres of liquids per year
Period of operation	1962 to present, application for expanded operations submitted
Waste Containment Facilities	
Method of containment/disposal	incineration, controlled landfilling of residuals, sludges and others with fly ash
Surface runoff control	site perimeter ditches collect runoff for treatment
Leachate collection system	site specific measures considered in site expansion application
On-site treatment facilities	available within waste neutralization facilities
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek, Lake Huron - Perch Creek, Sydenham River - Bear Creek.
Potential for flooding	none
Potential for surface runoff	none
Nearest receiving waters	Burton Drain and Bear Creek

Table 3.1.10a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	5 m of brown weathered till overlying grey till, localized surficial gravel
Thickness of overburden	40 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	detailed geologic, hydrogeologic and geochemical studies using 84 on-site piezometers
Details of shallow ground water flow	radial movement away from site imposed on generally north-easterly trend
Details of deeper ground water flow	northeasterly flow in regional aquifer at bedrock, calculated rate of downward movement from 0.3 to 0.9 cm/year
Relationship of waste to flow systems	wastes buried below watertable
Site Geochemistry	
Natural ground water quality characterization	local sampling by consultants and MOE
Leachate quality characterization	well documented
Shallow ground water quality on-site	well documented
Deeper ground water quality on-site	well documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	adequate
Adequacy of ground water quality monitoring	adequate as proposed in site expansion application

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

There is little topographic relief on site and natural surficial drainage may enter either the Thorton Drain or Talfourd, Perch or Bear Creeks. However, local drainage around the treatment and disposal areas is controlled and drainage returned to the plant for incineration or biological and activated carbon adsorption treatment with discharge to a local drain. Current surface and ground water monitoring would appear to be adequate but should be upgraded upon expansion of the site.

3.1.11 Site No. L-11. Cambrian Disposal Ltd.

Cambrian Disposal operates several deep disposal wells within Lambton County. Site L-11 known as CDL #6 operating Certificate of Approval Number A031807 is located on Lot 3 Concession 9, Township of Moore and is used to dispose of approximately 9,769 m^3 of cavern washing brine from the Sarnia petrochemical industry in 1985. The wastes have been injected into the Detroit River Group since 1974 with a total of approximately 1,295,000 m^3 being injected to 1985. Wells on neighbouring lots are monitored quarterly for evidence of contamination.

3.1.12 Site L-12 Moore Township

The Township of Moore operates a domestic refuse disposal site (Certificate of Approvals number A031808) serving the residents of Moore Township on Lot 21 Concession 5. The site accepts 3,600 tonnes of solid waste and 3,300 cubic meters of domestic sewage sludge. The solid waste disposed of consists of 70% domestic, 20% commercial and 10% brush, wood and scrap. The liquid waste disposed was entirely sewage sludge but was discontinued in 1984. Of the total 41 hectares, 18 hectares are to be filled.

Table 3.1.11. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-11
Registration Area: Sarnia
Site Certificate Number: A031807
Certificate Holder: Cambrian Disposal Ltd.
Location: Township of Moore UTM 397360E, 4747070N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industries
Location of waste disposal	0.01 hectare site
Waste characterization	wash brine
Quantities disposed of	9,769 m^3 per year, 1,295,000 m^3 injected to 1985
Period of operation	1974 to present
Waste Containment Facilities	
Method of containment/disposal	deep well injection via pipeline from Sarnia into Detroit River Group
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, flat topography
Site Hydrology	
Drainage basin	Sydenham River - Bear Creek
Potential for flooding	not applicable
Potential for surface runoff	not applicable
Nearest receiving waters	regional discharge possibly to St. Clair River

Table 3.1.11a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	not applicable
Thickness of overburden	not applicable
Underlying bedrock deposits	Bois Blanc and Bass Island Formations
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not applicable
Details of deeper ground water flow	westerly regional flow
Relationship of waste to flow systems	pressure build-up around well
Site Geochemistry	
Natural ground water quality characterization	monitoring by MOE
Leachate quality characterization	not documented
Shallow ground water quality on-site	not applicable
Deeper ground water quality on-site	not applicable
Attenuation characteristics of on-site deposits	not applicable
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	vertical migration from Detroit River Group to ground water aquifers via various hydraulic connections
Current evidence of leachate migration	none
Adequacy of surface water quality monitoring	none in effect - not necessary
Adequacy of ground water quality monitoring	wells on Lots 6 & 10 Con 8, Lot 6 Con 10, Lot 3 Con 11 Moore Twp are monitored

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.12. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-12
Registration Area: Sarnia
Site Certificate Number: A031808
Certificate Holder: Moore Twp.
Location: Township of Moore, UTM 386830E 4741870

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Moore Twp.
Location of waste disposal	18 hectares within 41 hectare site
Waste characterization	domestic, commercial, sewage sludge
Quantities disposed of	3,600 tonnes solid, 3,300 cu. meters of domestic sewage sludge per year
Period of operation	1969 to present, 20 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	not documented
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Clay Creek, Sydenham River - Bear Creek
Potential for flooding	none
Potential for surface runoff	moderate
Nearest receiving waters	Coyle Drain or Nichol Creek

Table 3.1.12a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glaciolacustrine clay w/silt and fine sand overlying clay till
Thickness of overburden	50 meters
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

The site is situated on the Lambton clay plain as described by Chapman and Putnam (1984). The site is situated in glaciolacustrine clays with silt and fine sand overlying clay till. The total depth of overburden is approximately 50 meters. No detailed hydrogeologic examinations are documented for this site. At present there is no surface water monitoring or ground water monitoring being conducted. The most likely pathway for leachate movement off-site would be by surface run-off and this has been noted at the site but has not presented a problem.

3.1.13 Site No. L-13 Unitec Inc. (previously Holmes Insulation)

Unitec Inc. (Holmes Insulation Inc.) waste disposal site off Scott Road (Certificate of Approval Number A031810) in the Township of Moore - West 1/2 Lot 22, Concession 12 serves the nearby Unitec Inc. (Holmes Insulation Inc.) manufacturing facilities. The site has been in operation since 1974. Disposal operations consist of controlled landfilling of non-hazardous solid industrial waste limited to rock wool insulation, including phenol formaldehyde resin and fiberglass, into individual landfill cells which are clay capped. The landfill site takes in an area of approximately 37 hectares. At present, approximately 19,100 tonnes of solid waste are received annually. Surface run-off and waste leachate are collected within individual cells which drain to a collection well and are pumped to a storage lagoon for use in a spray irrigation system. In the past, problems have been encountered with overflow of the storage lagoon especially in the spring.

Local site geology indicates that approximately 4 m of brown oxidized clay till overlies in excess of 30 m of gray clay till which overlies bedrock of Kettle Point Shale.

Table 3.1.13. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-13
Registration Area: Sarnia
Site Certificate Number: A031810
Certificate Holder: Unitec Inc., formerly Holmes Insultation Inc.
Location: Township of Moore, UTM 385850E, 4750950N

Sources of Information: MOE Approval files, Blue Water Inspection

	Description
Wastes Produced or Received at Site	
Location of waste production	off site at Holmes facilites
Location of waste disposal	32 hectares within 37 hectare site
Waste characterization	phenol formaldehyde resin, fiberglass
Quantities disposed of	19,100 tonnes per year
Period of operation	1974 to present, future use of 20 years expected
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling with clay capping of older portions
Surface runoff control	collection within individual landfill cells, transfer to holding lagoons for irrigation
Leachate collection system	leachate collection and tile drainage
On-site treatment facilities	spray irrigation
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	low due to perimeter berms and ditches
Potential for surface runoff	high potential in spring because of pond overflow
Nearest receiving waters	roadside ditch to Talfourd Creek

Table 3.1.13a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	4 m of brown oxidized till overlying grey till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	initial 12 m borehole, subsequent site geology verification from landfill excavation
Details of shallow ground water flow	not documented, local inflows into landfill cells expected
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	wastes buried below local watertable
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	elevated phenol, ammonia
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff from irrigation area
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	monitoring in effect for phenols, COD, ammonia on weekly basis
Adequacy of ground water quality monitoring	not documented

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

It is not presently known if surface and/or ground water monitoring systems have been implemented at this site. It is expected that the leachate will contain elevated levels of phenols and ammonia, however, once sprayed it is expected that the leachate characteristics will be indistinguishable from the farmland background waters. Drainage from the tile field is analyzed once a week for phenols and ammonia. Surface run-off from the spray irrigation area will be the most likely pathway for leachate movement off-site.

3.1.14 Site No. L-14. Shell

Shell Canada Limited operates an oil refinery along the banks of the St. Clair River approximately 12 km south of Sarnia. The refinery has been in operation since the 1950's and presently operates several waste sites. Site L-14, operated under Certificate of Approval number A031817, is a 0.25 hectare settling pond used to contain spent lime from process waters treatment. At present no wastes are being added to the pond. However, some stored wastes are being removed by Tricil and used for neutralizing purposes in their operations.

Hydrogeologic investigations were conducted by McLaren Plansearch in 1981 and 1982. The studies focused on a waste area discussed subsequently, however general geologic and hydrogeologic interpretations apply to the whole plant area. The plant site is underlain by the clay till plain present throughout the Sarnia area. Surficial drainage is locally directed towards Talfourd Creek which passes along the northwestern edge of the site. Numerous geotechnical boreholes and more recent hydrogeologic testholes (McLaren Plansearch, 1982) across the plant site suggest the silty clay till extends about 21 metres below surface and is underlain by a sand deposit at the bedrock contact. Auger refusal typically occurs

Table 3.1.14. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-14
Registration Area: Sarnia
Site Certificate Number: A031817
Certificate Holder: Shell Canada Limited, Corunna
Location: Township of Moore, UTM 382290E 4751400N

Sources of Information: MacLaren Plansearch (1982), MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	Shell facilities
Location of waste disposal	.25 hectare area within .4 hectare site
Waste characterization	calcium carbonate, spent lime
Quantities disposed of	not documented
Period of operation	presently not used, began operation in 1976
Waste Containment Facilities	
Method of containment/disposal	settling pond with surrounding dikes
Surface runoff control	not documented
Leachate collection system	none
On-site treatment facilities	not documented
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	low
Potential for surface runoff	none
Nearest receiving waters	Talfourd Creek, Marsh Creek and St. Clair River

Table 3.1.14a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	3 to 6 meters of brown oxidized till overlying grey till.
Thickness of overburden	typically 28 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	general plant site hydrogeologic investigations (McLaren Plansearch, 1982)
Details of shallow ground water flow	northwesterly to Talfourd Creek
Details of deeper ground water flow	westerly flow in regional aquifer at bedrock surface
Relationship of waste to flow systems	lagoon recharges local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	seepage through dike and surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

about 28 meters below surface. The hydraulic conductivity of the shallow tills varies from 1 x 10^{-10} m/s to 1 x 10^{-8} m/s and horizontal ground water movement within them is predicted to be northwestwards toward Talfourd Creek at a rate of about 10 centimeters per year.

No surface or ground water monitoring is presently in effect in the area of the lagoon. The most likely pathway for leachate movement off-site would be by seepage through the dike and surface run-off towards Talfourd Creek. Shallow ground water flow is directed northwesterly, again towards Talfourd Creek.

3.1.15 Site No. L-15. Cambrian Disposals Ltd.

Cambrian Disposal Site L-15 is located on Lot 3 Concession 7 in Moore Township. The site was listed under Certificate of Approval number A031818, however the Certificate of Approval was revoked in 1984. This deep disposal well was never used and was plugged in 1983.

3.1.16 Site No. L-16. Shell

As noted in section 3.1.14, Shell Canada Limited operates several waste sites within its plant site. Site L-16 the "north field" site (A031819) is a 7.7 hectare area that is used for the landfarming of 680 cubic meters per year of biosludge and oily wastes. Associated with the land farming is a sludge holding lagoon. The geologic and hydrogeologic characteristics were examined in a hydrogeologic study conducted by McLaren Plansearch (1982). The results indicated that a thick clay and silt unit underlies the north field site and that ground water flow occurs in a northwesterly direction towards Talfourd Creek. The hydraulic conductivity varies from 1 x 10^{-10} m/s to 1 x 10^{-8} m/s and this combined with

Table 3.1.15. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #	L-15		
Registration Area:	Sarnia	Sources of Information:	MOE files, Not registered, Disposal Agreement 327061 Mar. 73 384810 Feb. 76
Site Certificate Number:	A031818		
Certificate Holder:	Cambrian Disposals Ltd.		
Location:	Township of Moore UTM 397220E 4744130N		

	Description
Wastes Produced or Received at Site	never used
Location of waste production	plugged in 1983
Location of waste disposal	
Waste characterization	
Quantities disposed of	
Period of operation	
Waste Containment Facilities	
Method of containment/disposal	
Surface runoff control	
Leachate collection system	
On-site treatment facilities	
Gas control system	
Physiographic Setting of Site	
Site Hydrology	
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.16. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-16
Registration Area: Sarnia
Site Certificate Number: A031819, A031809
Certificate Holder: Shell Canada Limited, Corunna
Location: Township of Moore, UTM 382000E 4750870N

Sources of Information: MOE Approval Files, McLaren Plansearch Inc.

	Description
Wastes Produced or Received at Site	
Location of waste production	Shell facilities adjacent to landspreading area
Location of waste disposal	"north field" 7.7 hectare site, sludge holding lagoon
Waste characterization	biosludge, application for oily wastes disposal in north field under review leaded sludge
Quantities disposed of	680 cubic metres per year
Period of operation	1952 to present, 20 years estimated life.
Waste Containment Facilities	
Method of containment/disposal	controlled landspreading and sludge disposal
Surface runoff control	runoff directed to storm water collection system
Leachate collection system	collection provided in 1983 with tile drain installation
On-site treatment facilities	drainage to storm sewer if acceptable in quality or biox plant if not
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	low
Potential for surface runoff	none
Nearest receiving waters	Talfourd Creek

Table 3.1.16a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	3 to 6 metres of brown oxidized till overlying grey till
Thickness of overburden	35 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	13 piezometer sites, additional geotech. boreholes, lab and insitu permeability testing, ground water sampling.
Details of shallow ground water flow	northwesterly flow at 13 cm/year (insitu till permeabilities from $6x10^{-8}$ to 5×10^{-10} m/s)
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	previously recharged local watertable, leachates presently collected by tile drains
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	partial documentation available from Shell
Shallow ground water quality on-site	annual ground water monitoring beneath area since 1975 for pH, COD, phenol, nitrogen compounds; more extensive sampling including metals in 1982.
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high due to low soil permeability, measured CEC of 11 to 18 meq/100 gms
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	adequate
Adequacy of ground water quality monitoring	adequate

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

low horizontal hydraulic gradients across the site, results in a very low rate of ground water movement of approximately 10 centimeters per year.

Shell has conducted sludge and ground water monitoring of two shallow piezometers beneath the landfarming area since 1975. More areally representative ground water quality sampling was completed around the site perimeter by McLaren Plansearch (1982). The latter results suggest that the landfarming has had no apparent effect on general water quality parameters such as pH, conductivity, chloride, ammonia, nitrate, phenol, oil and grease and dissolved organic carbon. Accordingly there is no reason to suspect trace element migration.

Local run-off collection is provided around the landfarming area and directed into the storm water collection system. Drainage has also been enhanced by installation of a tile drainage system in 1983. There appears to be little potential effects from this site on the quality of St. Clair River water. Current ground water and surface water monitoring of this waste site would appear to be adequate.

Associated with the sludge landfarming operation are two old disposal areas; a leaded sludge disposal site, located northwest of the sludge holding lagoon, and a small lead disposal, located adjacent to Talfourd Creek. The leaded sludge disposal area was covered under Certificate of Approval number A031809. This certificate is no longer in affect and storage tanks have been built on both sites. The disposed sludge was not excavated and removed prior to construction. The leaded sludge disposal aréa is adequately covered by the monitoring wells installed between the disposal area and the creek. The small lead disposal area does not have monitoring wells nearby and residual contamination could migrate short distances to Talfourd Creek.

3.1.17 Site No. L-17. Town of Forest

The Town of Forest operates a disposal site under Certificate of Approval number A031901 on Lot 29 and 30 Concession 13, Township of Plympton. The site serves the Town of Forest and accepts approximately 500 tonnes of waste per year. The waste is composed primarily of rubble, bulk waste, brush cardboard and scrap metal. The total area to be filled is approximately 3.69 hectares within the 7.66 hectare site.

The site is located on the edge of the Wyoming Moraine which consists predominantly of a clay till. The overburden thickness is approximately 30 meters and overlies the Kettle Point formation shales. At present there is no monitoring of surface or ground water in effect at the site.

3.1.18 Site No. L-18. Cambrian Disposal Ltd.

Waste disposal site L-18 known as CDL #1 is a deep disposal well operated by Cambrian Disposal Ltd. under Certificate of Approval number A032001. The site has been operating since 1971 and a total of 6,803,000 m^3 of wash brine were injected to 1985. The site is located on Lot 7 Concession 1, Sarnia Township. Approximately 253,000 m^3 are disposed of annually. Wells adjacent to the site on Lot 10 Concession 1, Sarnia Township and Lot 4 Concession 12, Moore Township are monitored quarterly for evidence of contamination.

3.1.19 Site No. L-19. City of Sarnia

The City of Sarnia operates a landfill within the Township of Sarnia on the north half of Lot 12 Concession 3 (Certificate of Approval number A032002). The disposal operations occur on a 30 hectare parcel within the 40.5 hectare site. At present

Table 3.1.17. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory Summary Sheets (con't)...

GTC Site Identification # L-17
Registration Area: Sarnia
Site Certificate Number: A031901
Certificate Holder: Forest, Town of
Location: Township of Plympton UTM 417400E 4770160N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Town of Forest
Location of waste disposal	3.69 hectares within 7.66 hectare site
Waste characterization	rubble, bulk waste, brush, cardboard, scrap metal
Quantities disposed of	500 tonnes per year
Period of operation	1950 to present, 10 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	till moraine
Site Hydrology	
Drainage basin	Lake Huron - Hickory Creek
Potential for flooding	low
Potential for surface runoff	low
Nearest receiving waters	Hickory Creek

Table 3.1.17a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	30 meters
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	north westerly regional flow in aquifer at bedrock surface.
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	not documented
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.18. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-18
Registration Area: Sarnia
Site Certificate Number: A032001
Certificate Holder: Cambrian Disposals Ltd.
Location: Township of Sarnia

Sources of Information: MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industry
Location of waste disposal	0.01 hectare site
Waste characterization	wash brine
Quantities disposed of	253,000 m^3 per year, 6,803,000 m^3 brine injected to 1985
Period of operation	1971 to present
Waste Containment Facilities	
Method of containment/disposal	deep well injection into Detroit River Group, pipeline direct from Sarnia
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, flat topography
Site Hydrology	not applicable
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.18a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clayey silt to sandy till
Thickness of overburden	45 metres
Underlying bedrock deposits	Kettle Point Shales
Site Hydrogeology	
Extent of investigations	none documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	Injection into Detroit River Group
Site Geochemistry	
Natural ground water quality characterization	MOE monitoring and sampling of nearby domestic wells
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	MOE monitoring and sampling of nearby domestic wells
Attenuation characteristics of on-site deposits	low attenuation in disposal zone
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	vertical movement via hydraulic connections for Detroit River group to overlying formations
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect, not necessary
Adequacy of ground water quality monitoring	monitor adjacent wells Lot 10 Con. 1 Sarnia Twp., Lot 4 Con. 12 Moore Twp.

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.19. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-19
Registration Area: Sarnia
Site Certificate Number: A032002
Certificate Holder: Sarnia, City of
Location: Township of Sarnia, UTM 392340E 4755760N

Sources of Information: MOE Approval Files, Conestoga Rovers & Associates Ltd. (1985)

	Description
Wastes Produced or Received at Site	
Location of waste production	City of Sarnia, Twp. of Sarnia, Village of Point Edward
Location of waste disposal	30 hectares within 40.5 hectare site
Waste characterization	domestic, commercial, bulk, brush
Quantities disposed of	52,200 tonnes per year
Period of operation	1968 to present, 10 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	drainage ditch, tile drainage, sedimentation pond proposed
Leachate collection system	none, containment system proposed
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Lake Huron - Perch Creek
Potential for flooding	low
Potential for surface runoff	moderate to high
Nearest receiving waters	Perch Creek

Table 3.1.19a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	40 meters
Underlying bedrock deposits	Hamilton Formation shale-limestone
Site Hydrogeology	
Extent of investigations	report being prepared by Conestoga Rovers
Details of shallow ground water flow	report being prepared by Conestoga Rovers
Details of deeper ground water flow	northwesterly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	report being prepared by Conestoga Rovers
Leachate quality characterization	report being prepared by conestoga Rovers
Shallow ground water quality on-site	report being prepared by Conestoga Rovers
Deeper ground water quality on-site	report being prepared by Conestoga Rovers
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and subsurface seepage
Current evidence of leachate migration	leachate springs
Adequacy of surface water quality monitoring	city will implement program
Adequacy of ground water quality monitoring	city will implement program

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

approximately 52,500 tonnes per year of refuse are disposed from the City of Sarnia, Township of Sarnia and the Village of Point Edward. The waste is composed predominantly of domestic waste but some commercial (18%) and bulk waste (appliances, furniture, leaves, brush, - 27%) are also present.

The site is located on 40 meters of clay till overlying the Hamilton Formation shales and limestones. Prior to 1985, this landfill was poorly managed and presented several problems, such as, leachate springs, inadequate drainage, ponded water and poor cover material. Although there was no reported impact on ground water, there is potential for surface water to be adversely affected by run-off. In 1985, the City of Sarnia has carried out improvements to the site including the installation of a contaminant bern and leachate collection system along the east side and drainage ditches and a sedimentation pond. A consultant, Conestoga-Rovers and Associates, has been retained to assist in the site improvements.

At this point, the City plans to implement ground water and surface water monitoring programs. Further information on this site is required to determine the impact on the Perch Creek water shed.

3.1.20 Site No. L-20. C & R Sand and Gravel Ltd.

C & R Sand and Gravel Limited operates a 6 hectare landfill site in the Township of Sarnia, Lot 17, Concession 8 (Certificate of Approval number A032005). The site has been receiving non-hazardous solid waste consisting of logs, brush, construction rubble, and earth fill since 1970, in amounts averaging 200 tonnes per year. Presently, due to the non-hazardous nature of the waste material, no systems for

Table 3.1.20. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: L-20
Registration Area: Sarnia
Site Certificate Number: A032005
Certificate Holder: C and R Sand and Gravel Limited, Sarnia
Location: Township of Sarnia, UTM 389470E, 4761380N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	local construction contractors
Location of waste disposal	6 hectares within 8 hectare site
Waste characterization	inert construction debris, or non-hazardous waste material
Quantities disposed of	200 tonnes per year
Period of operation	1970 to present, 7 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfilling with soil capping
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	gravel deposit within sand plain
Site Hydrology	
Drainage basin	Lake Huron - Perch Creek
Potential for flooding	none
Potential for surface runoff	moderate
Nearest receiving waters	Perch Creek, Lake Huron

Table 3.1.20a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glaciolacustrine sand and gravel overlying clay till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	none
Details of shallow ground water flow	likely flow northward to Lake Huron
Details of deeper ground water flow	northwesterly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	wastes recharge local watertable
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	none documented
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	poor
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect, acceptable in light of reported waste composition
Adequacy of ground water quality monitoring	none in effect, acceptable in light of reported waste composition

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

containment or control of surface runoff or leachate seepage have been implemented. Also, no monitoring systems exist at present.

The site is an abandoned gravel pit that overlies clay till to bedrock (Kettle Point shale) at a depth of 30+ m. No hydrogeological data has been collected for the site, nor has any water geochemistry characterization been conducted. The most likely pathway for leachate movement off-site would be by subsurface seepage.

3.1.21 Site No. L-21. K & E Solid Waste Management

The K & E Solid Waste Management site is located in the Township of Sarnia, Lot 47 to 51, Front Concession. The total area of the site is 44.5 hectares of which 32 hectares are licensed for disposal (A032006). The site serves local industry and accepts approximately 15,000 tonnes of non-hazardous solid waste per year. The main wastes are foundry sand from Holmes Foundry, wood, metal and debris from Imperial Oil, Dow Chemical and CN Railway and polyethylene from Union Carbide.

The site is located in glaciolacustrine sand and gravel that overlies clay till. The total depth of overburden is approximately 30 meters and this overlies the Kettle Point shales. A preliminary hydrogeological assessment of the K & E site was conducted by B. Novakovic of the Ministry of the Environment to assess whether the disposal of waste has had an impact on the hydrogeologic environment and surface water. Results of surface water sampling of several on-site ponds revealed an increase above background of several constituents, namely specific conductance, chloride, sodium, organic nitrogen, iron biological oxygen demand and chemical oxygen

Table 3.1.21. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-21
Registration Area: Sarnia
Site Certificate Number: A032006
Certificate Holder: K and E Solid Waste Management
Location: Township of Sarnia, UTM 389700E, 4762450N

Sources of Information: MOE Approval Files, MOE (1983a)

	Description
Wastes Produced or Received at Site	
Location of waste production	local industries
Location of waste disposal	32 hectares within 44.5 hectare site
Waste characterization	non hazardous solid industrial waste (foundry sand, wood, metal)
Quantities disposed of	15,000 tonnes per year
Period of operation	1973 to present, future use of 15 years expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	contained on-site and pumped to roadside ditch
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	sand plain
Site Hydrology	
Drainage basin	Lake Huron, Perch Creek
Potential for flooding	high
Potential for surface runoff	high
Nearest receiving waters	Lake Huron via Michigan Avenue ditch and Wawanosh Drain

Table 3.1.21a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glaciolacustrine sand and gravel overlying clay till
Thickness of overburden	approx. 30 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	MOE preliminary hydrogeological assessment
Details of shallow ground water flow	likely shallow flow northward to Lake Huron
Details of deeper ground water flow	north westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local water table
Site Geochemistry	
Natural ground water quality characterization	none documented but surface water quality determined
Leachate quality characterization	none documented but surface water quality determined
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	low
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage in sand and gravel northward to Lake Huron, and surface water runoff
Current evidence of leachate migration	elevated parameters in surface water
Adequacy of surface water quality monitoring	occasional grab samples
Adequacy of ground water quality monitoring	monitoring wells are poorly located, inadequate monitoring

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

demand caused by disposal of wastes. In this study, an assessment of the impact of the surface water drainage on the receiving storm sewer water was prevented because of the lack of a suitable background water quality sample.

At present ground water and surface water monitoring is in effect but the locations of wells are inadequate to monitor ground water seepage from the site and surface water monitor consists of occasional grab samples. The most likely pathway for leachate movement would be by subsurface seepage in the sand and gravel towards Lake Huron to the north. Surface run-off is pumped to a main sewer trunk which flows to a roadside ditch (Michigan Avenue) which drains via Wawanosh Drain to Lake Huron.

3.1.22 Site No. L-22. Cambrian Disposal Ltd.

Cambrian Disposals deep well (CDL #2) registered under Certificate of Approvals Number A032007, is located on Lot 8 Concession 2, Township of Sarnia. The deep disposal well was utilized to inject wash brine into the Detroit River Group starting in 1971. The well was closed in 1981 with the last injections taking place in 1979. Over the life of the well 448,500 m^3 of waste were disposed. The Certificate of Approval was cancelled in 1984 and the well plugged in 1985.

3.1.23 Site No. L-23. Cambrian Disposal Ltd.

Cambrian Disposal deep well (CDL #7) Certificate of Approval Number A032008 is located on Lot 4 Concession 3, Township of Sarnia. The deep disposal well was opened in 1973 and closed in 1981. The last wastes (wash brines) were injected in 1980. During the operational life of the well 1,388,789 m^3 were

Table 3.1.22. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-22
Registration Area: Sarnia
Site Certificate Number: A032007
Certificate Holder: Cambrian Disposals Ltd.
Location: Township of Sarnia UTM 394910E, 4753320N

Sources of Information: MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industry
Location of waste disposal	0.01 hectare site
Waste characterization	wash brine
Quantities disposed of	448,500 m^3 brine, injected over well life
Period of operation	1971 - 1981, last injection 1979, well plugged in 1985
Waste Containment Facilities	
Method of containment/disposal	deep well injection into Detroit River Group via pipeline from Sarnia
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, flat topography
Site Hydrology	not applicable
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.22a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glacial till
Thickness of overburden	40 meters
Underlying bedrock deposits	Kettle Point Shales
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	injection in Detroit River Group
Site Geochemistry	
Natural ground water quality characterization	MOE monitoring and sampling of nearby domestic wells
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	MOE monitoring and sampling of nearby domestic wells
Attenuation characteristics of on-site deposits	low attenuation in disposal zone
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	vertical movement via hydraulic connections from Detroit River Group to overlying formations.
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect, not necessary
Adequacy of ground water quality monitoring	monitor adjacent wells, Lots 7 & 8 Con. 3, Lot 4 Con. 2

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.23. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-23
Registration Area: Sarnia
Site Certificate Number: A032008
Certificate Holder: Cambrian Disposal Ltd.
Location: Township of Sarnia UTM 397020E 4754550N

Sources of Information: MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industries
Location of waste disposal	0.01 hectare site
Waste characterization	wash brine
Quantities disposed of	1,388,789 m^3 injected to January 1980
Period of operation	1973 to 1981, last injection Jan 1980, well plugged in 1985
Waste Containment Facilities	
Method of containment/disposal	deep well injection to Detroit River Group
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, topography flat to slightly rolling
Site Hydrology	not applicable
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.23a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clayey silt to sandy till
Thickness of overburden	45 meters
Underlying bedrock deposits	Kettle Point Shales
Site Hydrogeology	
Extent of investigations	none documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	Injection into Detroit River Group
Site Geochemistry	
Natural ground water quality characterization	MOE monitoring and sampling of nearby domestic wells
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	MOE monitoring and sampling of nearby domestic wells
Attenuation characteristics of on-site deposits	low attenuation in disposal zone
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	vertical movement via hydraulic connections from Detroit River Group to overlying formation
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect, not necessary
Adequacy of ground water quality monitoring	quarterly monitoring of adjacent wells

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

injected into the Detroit River Group. Water wells adjacent to the site are monitored quarterly. The Certificate of Approval was cancelled in 1984 and the well plugged in 1985.

3.1.24 Site No. L-24. Cambrian Disposals Ltd.

Cambrian Disposals Ltd. deep well, (CDL #9) Certificate of Approval number A032010 is located on Lot 4 Concession 1, Township of Sarnia. 259,600 m^3 of wash brines were injected from 1975 to to 1979 when the operation was discontinued. Water wells adjacent to the site were monitored. The Certificate of Approval was cancelled in 1984 and the well plugged in 1985.

3.1.25 Site No. L-25. Esso Petroleum Canada

Esso Petroleum Canada Ltd. disposes of approximately 17,900 cubic meters per year of their Sarnia refinery wastes through landfarming on an eight hectare area in Range 2 Lots 10 and 11 in Lambton County. The wastes consist of lime sludges, aerobically digested activated sludges and oil sludges. The site is located approximately 5 km from the St. Clair River on a poorly drained portion of the regional till plain. The site is operated under Certificate of Approval number A032013. (Certificate no. changes to A30112). The tills are regionally known to limit infiltration and shallow ground water movement but no site specific geology or hydrogeology studies were available for review. Surface water and leachate from underdrain collector tiles are directed to the refinery's Biox plant. Shallow ground water is monitored by in place wells and sampled by the company.

Table 3.1.24. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-24
Registration Area: Sarnia
Site Certificate Number: A032010
Certificate Holder: Cambrian Disposals Ltd.
Location: Township of Sarnia UTM 397300E, 4752520N

Sources of Information: MOE files, not registered
Disposal agreement 315801 June 1972

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industries
Location of waste disposal	0.01 hectare site
Waste characterization	wash brine
Quantities disposed of	259,600 m^3 injected to July 1979
Period of operation	1975 to ?, lease was to be terminated and well plugged in 1985
Waste Containment Facilities	
Method of containment/disposal	deep well injection via tanker truck
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, flat topography
Site Hydrology	not applicable
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.24a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clayey silt to sandy till
Thickness of overburden	45 meters
Underlying bedrock deposits	Kettle Point Shales
Site Hydrogeology	
Extent of investigations	none documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	Injection into Detroit River Group
Site Geochemistry	
Natural ground water quality characterization	MOE monitoring and sampling of nearby domestic wells
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	MOE monitoring and sampling of nearby domestic wells
Attenuation characteristics of on-site deposits	low attenuation in disposal zone
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	vertical movement via hydraulic connections from Detroit River Group to overlying formations
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	not necessary
Adequacy of ground water quality monitoring	monitor adjacent wells, Lot 4, Con. 1, Plympton Twp, Lot 12 Con. 1 Sarnia Twp. Lot 9 Con 13 Enniskillen Twp.

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.25. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-25
Registration Area: Sarnia
Site Certificate Number: A032013 (reportedly changed to A30112)
Certificate Holder: Esso Petroleum Canada, Sarnia
Location: City of Sarnia UTM 387300E, 4755950N

Sources of Information: MOE approval files

	Description
Wastes Produced or Received at Site	
Location of waste production	off disposal site at Esso refinery
Location of waste disposal	controlled landforming on 8 of 38 hectare site
Waste characterization	lime sludge, aerobically digested activated sludge, oily sludges
Quantities disposed of	17,900 cu. meters per year
Period of operation	1977 to present, 30 year future use expected
Waste Containment Facilities	
Method of containment/disposal	landspreading of wastes
Surface runoff control	containment with perimeter dykes
Leachate collection system	collection provided by tile drain installation
On-site treatment facilities	not documented, collected water goes to Esso Biox plant
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	none
Potential for surface runoff	none
Nearest receiving waters	St. Clair River

Table 3.1.25a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	no site specific studies reviewed
Details of shallow ground water flow	controlled by tile drains, presumed otherwise not to be significant
Details of deeper ground water flow	north westerly flow in regional aquifer at bedrock surface
Relationship of waste to flow systems	waste leachates recharge local watertable
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	none documented
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	adequate
Adequacy of ground water quality monitoring	adequate monitoring by the company

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.1.26 Site No. L-26. Ed Johnson Construction Ltd.

Ed Johnson Construction Company Ltd. operates an 8.9 hectare waste disposal site off Blackwell Road. in Sarnia Township - northern sections of Lots 42 & 43 Concession 9. (Certificate of Approval Number A032014). Since 1981, the site has been receiving inert construction and demolition debris at the rate of approximately 45,900 tonnes per year.

The site itself is an abandoned sand pit that is kept dewatered by constant pumping at a rate of 9.1×10^{-3} m^3/s (120 GPM). Locally, up to 10 m of medium to fine sand overlies approximately 30 m of silty clay till, which overlies Kettle Point shale. The sands appear to be continuous from the site to Lake Huron. A hydrogeologic investigation was carried out by Conestoga-Rovers and Associates in 1979, prior to the disposal of waste at the site. At that time two (2) piezometers were installed and soil samples were collected in order to characterize the site. Several ground water quality samples were taken from the ponded water in the pit which is fed from the local perched unconfined aquifer. The water from this aquifer is used locally for irrigation purposes only and not for domestic purposes.

Currently the waste disposal site is operating approximately 5.0 m below the natural water table. Conestoga-Rovers and Associates (1979) anticipated that disposing of the fill below the water table will result in slightly increased BOD, COD, sulphates, and chlorides. In addition the wood waste would contribute organic constituents while the masonry waste contributes to increased hardness. However, due to the primarily inert character of the fill, contaminant release would be slow and not pollute the unconfined aquifer outside the site boundaries.

Table 3.1.26. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-26
Registration Area: Sarnia
Site Certificate Number: A032014
Certificate Holder: Ed Johnson Construction Ltd., Sarnia
Location: Township of Sarnia, UTM 391000E, 4763270N

Sources of Information: MOE Approval files, Conestoga Rovers & Associates (1979)

	Description
Wastes Produced or Received at Site	
Location of waste production	local construction contractors
Location of waste disposal	southeast area of landfilling area
Waste characterization	inert construction debris
Quantities disposed of	45,900 tonnes per year
Period of operation	1981 to present, future use of 10 years expected
Waste Containment Facilities	
Method of containment/disposal	landfilling in dewatered sand pits
Surface runoff control	none documented
Leachate collection system	provided in part by continuous dewatering of pit
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	sand plain
Site Hydrology	
Drainage basin	Lake Huron - Perch Creek
Potential for flooding	none
Potential for surface runoff	none
Nearest receiving waters	Lake Huron

Table 3.1.26a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	up to 10 m of fine-medium sand overlying clay till
Thickness of overburden	40 metres
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	initial hydrogeology study with 1 piezometer nest, 1 ground water sample
Details of shallow ground water flow	local inflow into pits, likely northward flow to Lake Huron
Details of deeper ground water flow	Northerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	wastes buried below watertable
Site Geochemistry	
Natural ground water quality characterization	several samples from ground water feed pond
Leachate quality characterization	none
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	poor
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect, will be required since net outflow will eventually occur from site

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

It is not presently known if leachate seepage is being monitored at this waste disposal site. It is anticipated that any leachate movement off-site will be via subsurface seepage.

3.1.27 Site No. L-27. Sombra Township

The Sombra Township (Wilkesport) site is a 4.5 hectare site serving Sombra Township and located on part Lot 11 Concession 12, Township of Sombra (Certificate of Approval number A032103). The site accepts 1600 tonnes per year of waste comprised of domestic (80%), commercial (10%) and brush and wood waste (10%). The site is near capacity with an estimated life expectancy of 3 years. The township is presently seeking a new site and this site will likely be closed in 1986.

Between at least 1975 and 1981, this landfill received separation filters from CIL Inc. These filters contained radium-226 at concentrations of up to 12,000 pCi/g. In 1982, a radiation survey of the landfill, by MOE, indicated an area of high radiation and other localized "hot spots". As a result, two truck loads of contaminated clay soil were removed from the landfill and transported to the CIL plant site. Another radiation survey by SENES Consultants Ltd. for CIL Inc. identified an additional two areas with elevated radium levels. Subsequently, four truck loads of contaminated soil were transported to CIL. Additional monitoring confirmed that all radium contaminated soil had been removed from the landfill.

The surficial geologic deposits on the site are predominantly clay till but on part of the site the clay till is overlain by young stream deposits. The total depth of overburden overlying the Kettle Point shales is approximately 50 meters. No hydrogeologic studies have been documented and no surface water or ground water monitoring is presently in effect. The MOE

Table 3.1.27. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-27
Registration Area: Sarnia
Site Certificate Number: A032103
Certificate Holder: Sombra Twp.
Location: Township of Sombra, UTM 386230E, 4731130N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Sombra Twp.
Location of waste disposal	4.5 hectare site
Waste characterization	domestic, commercial, brush, wood, and radium contaminated separation filters between 1975 and 1981
Quantities disposed of	1,600 tons per year
Period of operation	1969 to present, expected to be closed in 1986
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Sydenham River
Potential for flooding	moderate
Potential for surface runoff	moderate
Nearest receiving waters	Indian Creek, Sydenham River

Table 3.1.27a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till overlain by young stream deposits on part of site
Thickness of overburden	50 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	none documented
Details of shallow ground water flow	probably eastward to Indian Creek
Details of deeper ground water flow	south westward regional flow in bedrock aquifer
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	none documented
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and subsurface seepage
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	none in effect, occasional monitoring of Indian Creek by MOE
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

have occasionally monitored the water quality of nearby Indian Creek and the results do not indicate an environmental impact caused by the landfill. MOE have sampled nearby domestic wells in the bedrock aquifer and analyzed the samples for radiological parameters. The results showed what are believed to be background levels. The most likely pathway for leachate movement off-site is via subsurface seepage or surface run-off.

3.1.28 Site No. L-28. Cambrian Disposal Ltd.

Site No. L-28 is located on Lot 23 Concession 6 in the Township of Sombra. The deep disposal well registered under Certificate of Approval number A032104 was approved for use in 1974 but has never been used. The well was intended to be used for the injection of wash brines and a life expectancy of 10 years was calculated. Water wells in the area have been identified for monitoring if disposal operations commence.

3.1.29 Site No. L-29. CIL

The Canadian Industries Limited (CIL, Lambton Works) plant near Courtright produces chemical fertilizers. The plant site is located approximately 1 km east of the St. Clair River in Lots 3 and 4 Concession 15 of the Municipality of Sombra. There is little topographic relief but surface drainage is either directed towards the river or eastward into Clay Creek. Geotechnical borehole logs were not available for the site and site specific studies have never been done.

Present operations and waste storage facilites were originally approved by the Ontario Water Resources Commission in 1966. The fertilizer manufacture includes the use of phosphate rock which naturally contains minor amounts of radioactive radium

Table 3.1.28. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: L-28
Registration Area: Sarnia
Site Certificate Number: A032104
Certificate Holder: Cambrian Disposals Ltd.
Location: Township of Sombra

Sources of Information: MOE files, not registered,
Disposal Agreements 358383 june 74
358384 june 74
358385 aug. 74

	Description
Wastes Produced or Received at Site	
Location of waste production	Sarnia petrochemical industry
Location of waste disposal	0.01 hectare site
Waste characterization	(proposed) wash brine
Quantities disposed of	zero to date
Period of operation	never used
Waste Containment Facilities	
Method of containment/disposal	proposed deep well injection
Surface runoff control	not applicable
Leachate collection system	not applicable
On-site treatment facilities	not applicable
Gas control system	not applicable
Physiographic Setting of Site	clay till plain, flat topography
Site Hydrology	not applicable
Drainage basin	
Potential for flooding	
Potential for surface runoff	
Nearest receiving waters	

Table 3.1.28a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clayey silt to sandy till
Thickness of overburden	45 metres
Underlying bedrock deposits	Kettle Point Shales
Site Hydrogeology	
Extent of investigations	none documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	no wastes injected
Site Geochemistry	
Natural ground water quality characterization	MOE monitoring and sampling of nearby domestic wells
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	MOE monitoring and sampling of nearby domestic wells
Attenuation characteristics of on-site deposits	low attenuation in disposal zone
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	
Current evidence of leachate migration	
Adequacy of surface water quality monitoring	
Adequacy of ground water quality monitoring	monitoring wells identified

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.1.29. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-29
Registration Area: Sarnia
Site Certificate Number: A032105
Certificate Holder: C.I.L. Inc., Courtright
Location: Township of Sombra, UTM 381770E 4735460N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	CIL Lambton Works
Location of waste disposal	0.1 hectares within existing on site waste storage area
Waste characterization	once only disposal of low level radioactive waste transferred from Sombra Township landfill
Quantities disposed of	not documented (approximately six truckloads)
Period of operation	1982 - present
Waste Containment Facilities	
Method of containment/disposal	landfill in one of 2-20 hectare gypsum ponds; nearby "bunker" for temporary storage of low level radioactive waste
Surface runoff control	perimeter ditches provided around ponds to collect leachate and storm water
Leachate collection system	none
On-site treatment facilities	yes, plant is shutting down, gypsum pond waters are being treated with lime and pH adjustment and discharged
Gas control system	none required
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	surface runoff directed to St. Clair River
Potential for flooding	wastes fully saturated in pond
Potential for surface runoff	low
Nearest receiving waters	St. Clair, Clay Creek

Table 3.1.29a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	45 meters
Underlying bedrock deposits	Port Lambton shale or sandstone
Site Hydrogeology	
Extent of investigations	2 geotechnical boreholes within pond area
Details of shallow ground water flow	not documented
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	waste leachates recharge watertable
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	none
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	none documented
Adequacy of surface water quality monitoring	reportedly conducted
Adequacy of ground water quality monitoring	reportedly conducted

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

and uranium. These elements eventually appear in a waste gypsum slurry which is discharged into two 50 hectare holding ponds. The ponds also contain phosphate, ammonia and fluoride with a water pH of 1.0. Drainage ditches around the perimeter of the ponds collect any pond seepage. Surface water and ground water monitoring is conducted.

In the period 1975 to 1981, separation filters containing radium concentrations as high as 12,000 pCi/g from the CIL manufacturing process were disposed at the Sombra Township (Wilkesport) Landfill Site (see Section 3.1.27). This disposal resulted in areas of high radiation exposure rate and localized hotspots. Under the direction of MOE and the Ministry of Labour, CIL removed two truckloads of contaminated soil from the landfill for storage at the edge of one of CIL's gypsum ponds. The contaminated soil was then accidently pushed into the pond. Another radiation survey of the landfill identified two areas of elevated exposure rate and a further four truckloads of contaminated soil was removed to the CIL location.

As a result, a Certificate of Approval Number A032105 was given to CIL to cover the once only disposal of the low level radioactive waste, contaminated soil and debris collected from the Sombra Township Landfill. The wastes are presently contained inside the walls of the gypsum pond. All radioactive materials (i.e., separation filters) are now stored in a concrete bunker on-site.

3.1.30 Site No. L-30. Welland Chemicals Ltd.

Welland Chemicals Limited located on Scott Road, within the Sarnia Indian Reserve, a few kilometers from the city limits of Sarnia, has on its property a landfill, drum storage and liquid

Table 3.1.30. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: L-30
Registration Area: Sarnia
Site Certificate Number: not registered
Certificate Holder: Welland Chemical Ltd
Location: Sarnia Indian Reserve No. 45, UTM

Sources of Information: P&R Group, GL Assoc. Ltd. (1981)
O.H. Materials Co. (1984)

	Description
Wastes Produced or Received at Site	
Location of waste production	on-site facilities
Location of waste disposal	landfilling
Waste characterization	aluminum chloride and associated reactants
Quantities disposed of	unknown
Period of operation	pre 1972
Waste Containment Facilities	
Method of containment/disposal	landfilling
Surface runoff control	Drainage collection system and treatment ponds
Leachate collection system	Subsurface drainage collection system
On-site treatment facilities	Treatment of pond water, if necessary, prior to discharge
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	St. Clair River - Talfourd Creek
Potential for flooding	low
Potential for surface runoff	contained by surface runoff controls
Nearest receiving waters	Talfourd Creek

Table 3.1.30a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	3 to 5 m of brown or mottled till overlying gray till
Thickness of overburden	35 meters
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	18 borehole/piezometer installations to max depth of 6 m, insitu permeability testing, ground and surface water quality sampling
Details of shallow ground water flow	locally eastward flow at less than 1 cm/year (till permeabilities less than 3×10^{-7} cm/sec)
Details of deeper ground water flow	westerly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	wastes could be buried below watertable
Site Geochemistry	
Natural ground water quality characterization	shallow "background" piezometer quality may not be representative
Leachate quality characterization	elevated Ca, HCO_3, Cl noted in ground waters in 1981, TOC, heavy metals in surface waters
Shallow ground water quality on-site	as above
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	poor quality surface water releases noted in 1981 but improving with existing controls
Adequacy of surface water quality monitoring	adequate with present controls
Adequacy of ground water quality monitoring	downgradient monitoring not installed, source of poor quality ground water on-site not known but general ground water quality improving

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

effluent storage pond. This industry, which produces anhydrous aluminum chloride, was previously known as the St. Clair Chemical Company. The process utilizes chlorine, which is shipped to the plant by rail, and high grade aluminum. In addition, a separate operation involving the repackaging of chlorine gas into smaller containers also occurs on site. All liquid wastes from both operations passes through a lagoon system prior to discharge to a sewer which discharges to the Scott Road drain.

In 1974 and 1975 St. Clair Chemical disposed of an unknown quantity of anhydrous aluminum chloride which did not meet their purity specifications for marketing. This material was buried on site, possibly in 45-gallon steel drums. The quantity, exact location and depth of this waste are not specifically known. The presumed site of the landfill has been covered and graded, but not revegetated.

Local geology consists of 3 to 5 m of brown weathered clay till overlying in excess of 30 m of gray till overlying bedrock of Kettle Point Shale. Site investigations by the Proctor and Redfern Group with Gartner Lee Associates Limited (1981), and O.H. Materials Co. (1984) produced a total of 18 boreholes with piezometer installations to a maximum depth of 6 m. In addition permeability testing and surface and ground water quality sampling and analyses have been done.

Surface run-off at the site was collected in perimeter ditches that empty into Talfourd Creek. Water samples from these ditches were the first indication of leachate migration. Recent clean-up of surface on-site storage locations, construction of a subsurface drainage collection system for surface water and two on-site surface water treatment ponds have improved the quality of water discharged from the plant

property. Ground water samples collected from on-site monitoring wells indicate an improvement in water quality since 1981.

3.1.31 Site No. L-31. Walpole Island Indian Reserve

A small (0.3 hectare) waste disposal landfill, identified as Site No. I-9 by Federal agencies, exists on the Walpole Island Indian Reserve. The site was used for an extended period of time, perhaps 30 years, for disposal of domestic garbage, junk (old cars, etc.) and garage waste by island residents and summer cottagers. It was closed and covered over in 1976 because of concerns about health hazards due to its proximity to some residences. The land is very flat and lowlying, only several feet above the nearby St. Clair River. The water table is close to the surface (less than 1.5 m deep) and the local geology consists of deltaic sands and silts.

A synopsis by Environment Canada indicates evidence of leachate, however, the report does not disclose its nature. Leachate migration off site is likely due to both surface run-off and subsurface seepage to the water table.

3.2 Kent County

Within Kent County, five (5) waste disposal sites were examined. Very little information was available for these sites and the summaries have been compiled predominantly from information available from the MOE. Further information available on these sites is incorporated into tables included in this section.

Table 3.1.31. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # L-31
Registration Area: Sarnia
Site Certificate Number: I-9
Certificate Holder: Federal government
Location: Walpole Island Indian Reserve, UTM 374900E 4717300N

Sources of Information: Environment Canada (1983)

	Description
Wastes Produced or Received at Site	
Location of waste production	local residents
Location of waste disposal	0.3 hectare site
Waste characterization	domestic garbage
Quantities disposed of	unknown
Period of operation	approximately 1945 to 1976
Waste Containment Facilities	
Method of containment/disposal	uncontrolled landfilling
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	sandy delta
Site Hydrology	
Drainage basin	St. Clair River
Potential for flooding	high
Potential for surface runoff	moderate
Nearest receiving waters	St. Clair River

Table 3.1.31a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	deltaic sands and silts
Thickness of overburden	30 m
Underlying bedrock deposits	Kettle Point shales
Site Hydrogeology	
Extent of investigations	none
Details of shallow ground water flow	none documented, likely westerly flow towards St. Clair River
Details of deeper ground water flow	none documented
Relationship of waste to flow systems	waste leachates recharge local watertable
Site Geochemistry	
Natural ground water quality characterization	none documented
Leachate quality characterization	none documented
Shallow ground water quality on-site	none documented
Deeper ground water quality on-site	none documented
Attenuation characteristics of on-site deposits	poor
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and subsurface seepage into nearby depression
Current evidence of leachate migration	yes
Adequacy of surface water quality monitoring	none present
Adequacy of ground water quality monitoring	none present

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.2.1 Site No. K-1. Camden Township

The Township of Camden operates a 6 hectare disposal site which only serves the township on Lot 5 Concession 3 (Certificate of Approval number A021303). The site receives approximately 900 tonnes of waste a year of which 90% is domestic with the remaining being composed of ash, concrete, lumber and roofing materials.

The site is situated in a medium to fine sand deposit which overlies the glacial till. The depth of sand is approximately 2 meters with the total depth of drift over the bedrock (Kettle Point shales), being approximately 16 meters. No detailed hydrogeologic studies have been conducted and no ground water or surface water monitoring is presently being done. The most likely pathway for leachate movement off site is via subsurface seepage.

3.2.2 Site No. K-2. Dresden Tile Yard Ltd.

The Dresden Tile Yard site is located in the Township of Camden, Lot 8 Concession 5 (Certificate of Approval number A021304). The 8 hectare site serves the Town of Dresden and accepts approximately 500 tonnes per year of waste. The waste accepted is predominantly incinerator ash and construction debris such as asphalt and tar paper (95%) and some commercial wastes (5%).

The site is located on the Lambton clay plain and the local surficial deposits are clay intermixed with silt and fine sand. The total depth of the overburden is 16 meters overlying the Kettle Point shales. No ground water or surface water monitoring is in effect at present and no detailed hydrogeologic evaluation have been documented.

Table 3.2.1. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification: K-1
Registration Area: Sarnia
Site Certificate Number: A021303
Certificate Holder: Camden Township
Location: Township of Camden UTM 412000E 4711300N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	Camden Township
Location of waste disposal	6 hectare within 20 hectare site
Waste characterization	domestic, (90%) some ash, concrete, lumber (10%)
Quantities disposed of	900 tonnes per year
Period of operation	1972 to present, 16 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	sand plain
Site Hydrology	
Drainage basin	Sydenham River
Potential for flooding	moderate
Potential for surface runoff	moderate
Nearest receiving waters	tributary of Sydenham River

Table 3.2.1a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	medium to fine sand
Thickness of overburden	16 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	none
Details of shallow ground water flow	not documented
Details of deeper ground water flow	southwesterly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	moderate
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.2.2. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # K-2
Registration Area: Sarnia
Site Certificate Number: A021304
Certificate Holder: Dresden Tile Yard Ltd.
Location: Township of Camden UTM 403500E 4718050N

Sources of Information: MOE Approval Files

	Description
Wastes Produced or Received at Site	
Location of waste production	local municipalities and industry
Location of waste disposal	8 hectares within 35 hectare site
Waste characterization	some commercial (5%), incinerator ash, asphalt, tar paper (95%)
Quantities disposed of	500 tonnes per year
Period of operation	1972 to present, 50 years future use expected
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	not documented
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay plain
Site Hydrology	
Drainage basin	Sydenham River
Potential for flooding	high
Potential for surface runoff	moderate
Nearest receiving waters	Molly's Creek

Table 3.2.2a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay with silt and fine sand
Thickness of overburden	16 meters
Underlying bedrock deposits	Kettle Point shale
Site Hydrogeology	
Extent of investigations	none
Details of shallow ground water flow	not documented
Details of deeper ground water flow	south westerly flow in regional aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.2.3 Site No. K-3. Raleigh Township

The Township of Raleigh operates a small waste disposal site under Certificate of Approval Number A021903 on Lot 6 Concession 8, Township of Raleigh. 3,100 tonnes of inert domestic waste are accepted annually on the 1 hectare site.

The site is situated in the clay-till plain. 30 meters of overburden overlie the Hamilton Formation. Documented information for this site is scarce, probably due to its small size. No hydrogeological studies are documented.

3.2.4 Site No. K.4. Romney Township

The Township of Romney operates a waste disposal site on Lot 11 Concession 4 in the Township of Romney. The 0.8 ha site (Certificate of Approval number A022002) accepts 700 tonnes of waste per year. No data were available for this site.

3.2.5 Site No. K-5. J. Stonehouse

The J. Stonehouse site is located on Lot 13 Concession 9 in the Township of East Tilbury. The site operates under Certificate of Approval number A022102 and accepts approximately 1,000 tonnes of waste per year on the 0.8 hectare site. No data were available for this site.

Table 3.2.3. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # K-3
Registration Area: Windsor
Site Certificate Number: A021903
Certificate Holder: Raleigh Twp.
Location: Township of Raleigh

	Description
Wastes Produced or Received at Site	
Location of waste production	local domestic
Location of waste disposal	1 hectare within 2 hectare site
Waste characterization	3100 tonnes per year
Quantities disposed of	not documented
Period of operation	not documented
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	not documented
Leachate collection system	not documented
On-site treatment facilities	not documented
Gas control system	not documented
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Thames River - Jeannettes Creek
Potential for flooding	high
Potential for surface runoff	moderate
Nearest receiving waters	tributary of Jeannettes Creek

Table 3.2.3a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	30 meters
Underlying bedrock deposits	Hamilton formation limestone shale
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	northwesterly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none if effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.2.4. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification #	K-4	Sources of Information:
Registration Area:	Windsor	
Site Certificate Number:	A022002	
Certificate Holder:	Romney Twp.	
Location:	Township of Romney	

	Description
Wastes Produced or Received at Site	
Location of waste production	local
Location of waste disposal	0.8 hectare within 2 hectare site
Waste characterization	inert wastes
Quantities disposed of	700 tonnes per year
Period of operation	not documented
Waste Containment Facilities	
Method of containment/disposal	landfill trench
Surface runoff control	not documented
Leachate collection system	not documented
On-site treatment facilities	not documented
Gas control system	not documented
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Lake Erie
Potential for flooding	moderate
Potential for surface runoff	moderate
Nearest receiving waters	East Two Creeks, Lake Erie

Table 3.2.4a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	40 meters
Underlying bedrock deposits	Hamilton Formation limestone shale
Site Hydrogeology	
Extent of investigations	not document
Details of shallow ground water flow	not documented
Details of deeper ground water flow	southwesterly flow in regional aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Table 3.2.5. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # K-5
Registration Area: Windsor
Site Certificate Number: A022102
Certificate Holder: Stonehouse, J.
Location: Township of East Tilbury

Sources of Information:

	Description
Wastes Produced or Received at Site	
Location of waste production	local
Location of waste disposal	0.8 hectares within 22 hectare site
Waste characterization	domestic, inert wastes
Quantities disposed of	1,000 tonnes per year
Period of operation	not documented
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	not documented
Leachate collection system	not documented
On-site treatment facilities	not documented
Gas control system	not documented
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Thames River - Baptiste Creek
Potential for flooding	moderate
Potential for surface runoff	moderate
Nearest receiving waters	Baptiste Creek

Table 3.2.5a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	40 meters
Underlying bedrock deposits	Hamilton Formation limestone shale
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	not documented
Details of deeper ground water flow	south easterly regional flow in aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	not documented
Adequacy of surface water quality monitoring	none in effect
Adequacy of ground water quality monitoring	none in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.3 Essex County

Within Essex County, seven (7) waste disposal sites were examined.

3.3.1 Site No. E.1. Allied Chemical

Allied Chemical operates a chemical plant on the northern town limits of Amherstburg approximately 12 km south of Windsor. The plant produces soda ash, calcium chloride and hydrogen fluoride from natural sodium chloride brines and limestone quarried on its property. The plant site property extends approximately 2 1/2 km eastward from the Detroit River with waste storage areas located about 1.6 km from the river. Big Creek flows southward across the site into Lake Erie. The plant site is underlain by 5 to 15 m of poorly permeable clay tills resting on limestone bedrock.

Since 1957, Allied's process effluents have been discharged to a series of settling ponds situated on clay tills. The effluents consist of a slurry of lime residues and higher TDS water containing elevated calcium, sodium, chloride, fluoride and sulfate. Decant waters from these ponds were originally discharged through open ditches into the Detroit River. During the period from 1963 to 1982, the effluents were directed into the former "Amherstburg" quarry also located on site. The quarry covers approximately 61 hectares. Throughout 1977 and 1978, contaminated seepage (driven by elevated ground water levels in the quarry) began to create ground water quality concerns in domestic wells downgradient from the quarry. The plume of contaminated ground waters presently extends up to 2000 m southward from the quarry towards Big Creek marsh rather than westward towards the Detroit River. Any ground water discharge into Big Creek eventually enters Lake Erie.

Table 3.3.1. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # E-1
Registration Area: Windsor
Site Certificate Number: A010201 (new setting basin),
A010203 (old basin - Amherstburg quarry
Certificate Holder: Allied Chemical
Location: Town of Amherstburg

Sources of Information: Golder Associates, IEC and McLaren site reports; MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	manufacturing facilities adjacent to basins
Location of waste disposal	Amherstburg quarry (61 hectares), new engineered basin (30 hectares)
Waste characterization	lime residues containing leachates with elevated Ca, NA, Cl
Quantities disposed of	not documented
Period of operation	original settling basins 1963 to 1982, new basin 1982 to present
Waste Containment Facilities	
Method of containment/disposal	deposition of lime residues in quarry, new dyked basin
Surface runoff control	provided by dykes around new basins, naturally by quarry settling of original
Leachate collection system	naturally provided by pumping of Mailloux quarry adjacent to Amherstburg quarry
On-site treatment facilities	settling basins
Gas control system	none
Physiographic Setting of Site	clay plain
Site Hydrology	
Drainage basin	Lake Erie - Big Creek
Potential for flooding	none
Potential for surface runoff	none
Nearest receiving waters	Big Creek

Table 3.3.1a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	silty clay till
Thickness of overburden	8 meters
Underlying bedrock deposits	Detroit River Group - Lucas Formation limestone
Site Hydrogeology	
Extent of investigations	highly detailed and extensive site investigations
Details of shallow ground water flow	locally from basins towards Big Creek
Details of deeper ground water flow	southerly movement through bedrock about 5 m/yr
Relationship of waste to flow systems	old settling basin leachates directly enter bedrock
Site Geochemistry	
Natural ground water quality characterization	higher TDS waters Ca-Mg/SO_4-HCO_3 composition
Leachate quality characterization	elevated Ca, Na, Cl, Fl, SO_4
Shallow ground water quality on-site	locally affected near old settling basin
Deeper ground water quality on-site	affected up to 2000m southward from old settling basin
Attenuation characteristics of on-site deposits	limited
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage from old settling basin
Current evidence of leachate migration	seepage documented, impact of suface water discharges to Big Creek investigated
Adequacy of surface water quality monitoring	MOE monitoring of Big Creek
Adequacy of ground water quality monitoring	complete piezometer and domestic well network monitored as per MOE approval

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

The MOE responded to the situation through investigations and supervision of remedial actions (Golder Associates 1978, 1980, 1983). The waste site is currently registered under Certificate of Approval A010203 which imposes conditions on ground water elevations in the quarry, capping of the waste residues with lower permeability gypsum wastes and detailed ground water monitoring. Golders (1983) concluded that waste leachates from the quarry will continue to be delivered to the local groundwaters for many tens of years at loadings which will gradually decrease.

A new settling basin (Certificate of Approval A010201) has been in use since 1982 in the northeastern portion of the plant site. Its environmental impact has been assessed by McLaren (1981). The basin is situated on 11 to 17 m of clay till gently sloping eastward toward Big Creek. The tills have hydraulic conductivity values in the order of 10^{-8} to 10^{-9} m/s. Based on mathematical modelling and isotope sampling (Golder, 1981), the downward rate of flow of basin waters into the bedrock is estimated to be approximately 0.35 L/s with a transit time of about 50 years. This seepage would then travel easterly. No ground water discharge into Big Creek is expected.

3.3.2. Site No. E.2. Essex County, Colchester North

The County of Essex has a 41 hectare waste disposal site located in Colchester North Township - Lot 14, Concession 7 operating under Certificate of Approval number A011101. Since 1970 the site has been serving the municipality of Amherstburg, Anderdan, Colchester North, Colchester South, Essex, Harrow, Malden, Sandwich West and part of Sandwich South. Disposal at the site consists of a ramp-type operation, with cells being excavated into the clay soil, and the soil

Table 3.3.2. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # E-2
Registration Area: Windsor
Site Certificate Number: A011101
Certificate Holder: Essex County
Location: Township of Colchester North,

Sources of Information: MOE Approval Form, Dillon (1983), Dominion Soils (1972)

	Description
Wastes Produced or Received at Site	
Location of waste production	local municipalities
Location of waste disposal	Colchester North Township - Lot 14, Conession 7
Waste characterization	domestic, commercial, non-hazardous, sewage sludge
Quantities disposed of	27,600 tonnes per year
Period of operation	1970 to present, estimated site life 14.5 years
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling with clay capping (ramp type operation)
Surface runoff control	perimeter ditches, dyked leachate storage pits, landfill drainage system preposed
Leachate collection system	leachate collection ditches, leachate from ditch pumped to storage area on top of landfill, engineered leachate collection system designed by M.M. Dillon (1983)
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Lake Erie - Cedar Creek
Potential for flooding	none
Potential for surface runoff	high
Nearest receiving waters	Cedar Creek

Table 3.3.2a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	3 m of brown weathered till overlying gray till, locally interbedded sands
Thickness of overburden	25 meters
Underlying bedrock deposits	Detroit River Group - Lucas Formation, limestone
Site Hydrogeology	
Extent of investigations	initial geologic inspection, recent remedial action studies
Details of shallow ground water flow	information incomplete, leachate mounding because cover soils more permeable than native tills (permeability approx. 1×10^{-7} cm/sec)
Details of deeper ground water flow	southeasterly regional flow at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	completed by MOE (1978), (1983)
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	none
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	numerous leachate springs
Adequacy of surface water quality monitoring	adequate considering proposed leachate controls
Adequacy of ground water quality monitoring	adequate

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

removed being used as cover material. Commercial, municipal and sewage sludge waste constitute the majority of the waste received at the site. Waste volumes are recorded by weight with a current annual average being about 27,000 tonnes.

Dominion Soil Investigations Limited completed a soils investigation in 1972. Generally, there is 24 m to 30 m of silty clay till overlain by approximately 3 m of brown weathered till overlain by approximately 0.5 m top soil. The local topography is very flat and surface drainage is poor. The local water table is generally within 3 m of the ground surface.

Ground water monitoring piezometers were installed in 1982 to monitor for leachate contamination. Currently, leachate seeps at the waste disposal site are controlled by a collection ditch system along the north and west boundaries. The leachate collected is then pumped back to a dyke storage area at the top of the landfill at regular intervals. Leachate quality characterization was conducted by the MOE, 1983.

A more permanent leachate control system is currently under review and is expected to be installed in the very near future. This will eliminate the possibility of any leachate migrating from the disposal site via surface water run-off, seepage break-outs, or ground water seepage.

3.3.3 Site No. E-3. Essex County, Maidstone

The Essex County Sanitary Landfill No. 3 is located in Maidstone Township, County of Essex. (Certificate of Approval number A011501) The site occupies approximately 100 hectares of Lots 14 and 15 in Concessions 4. The County of Essex owns the site. Nine municipalities currently use the landfill:

Table 3.3.3. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # E-3
Registration Area: Windsor
Site Certificate Number: A011501
Certificate Holder: Essex County
Location: Township of Maidstone

Sources of Information: MOE files, Gartner Lee (1980)
M.M. Dillon (1983)

	Description
Wastes Produced or Received at Site	
Location of waste production	local municipalities
Location of waste disposal	domestic, commercial, sewage sludge
Waste characterization	220,000 tonnes per year
Quantities disposed of	Site life estimated at 9.5 years
Period of operation	
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling, trench and fill and open face ramping
Surface runoff control	ditches to drain
Leachate collection system	constructed and operational in 1985
On-site treatment facilities	none, leachate storage reservoir then truck to sewage treatment plant for disposal
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Lake St. Clair-Puce River
Potential for flooding	none
Potential for surface runoff	high
Nearest receiving waters	Standish Municipal Drain, Puce River

Table 3.3.3a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay till
Thickness of overburden	40 meters
Underlying bedrock deposits	Hamilton Formation - limestone shale
Site Hydrogeology	
Extent of investigations	study by Gartner-Lee and Associates (1983)
Details of shallow ground water flow	flow tends towards ditch to west of site, ditch in discharge zone and a hydrogeological boundry
Details of deeper ground water flow	northerly flow in regional aquifer at bedrock surface
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	documented by Gartner Lee (1983)
Leachate quality characterization	well documented by Dillon (1983)
Shallow ground water quality on-site	well documented by Gartner Lee (1983)
Deeper ground water quality on-site	well documented by Gartner Lee (1983)
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	leachate springs occuring some degradation of surface water noted
Adequacy of surface water quality monitoring	routine monitoring in effect - frequency of monitoring shall be increased in light or problems identifified
Adequacy of ground water quality monitoring	monitoring in effect

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Tilbury North, Tilbury West, Rochester, Maidstone, Bell River, St. Clair Beach, Tecumseh, Sandwich South, and Windsor. Landfill No. 3 receives domestic, commercial and non-hazardous solid industrial wastes. There is also sludge disposal from municipal sewage treatment plants. At present the site receives approximately 220,000 tonnes of waste annually.

Local geology consists of 3 m of weathered clay over clay till to a depth of approximately 36 m. This is underlain by a limestone bedrock. The local topography is generally flat with a very mild slope to the west. The average ground water level is approximately 2.5 m below ground surface.

As a result of leachate problems, a leachate collection system has been installed around the perimeter of the landfill. Leachate is stored in a reservoir until it is trucked to a sewage treatment plant for disposal.

3.3.4 Site No. E-4. City of Windsor, East Side

The East Side Landfill, north of Tecumseh Road in Windsor is a 7 hectare solid waste disposal landfill that was operated by the City of Windsor (Certificate of Approval Number C010102). The landfill site, closed in 1973, was operated as a controlled landfill and received approximately 300 tons/day of waste throughout its life. The waste received was predominantly commercial, domestic, and industrial waste and included hauled sewage and demolition and excavation materials as well as trees and brush.

Local geology indicates a clay till in excess of 2 m overlying approximately 30 m of clay which overlies bedrock of Hamilton Group shale and limestone. The local water table is about 1.8 m below ground surface. An inventory done by the MOE in

Table 3.3.4. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # E-4
Registration Area: Windsor
Site Certificate Number: C010102
Certificate Holder: City of Windsor
Location: City of Windsor, UTM

Sources of Information: MOE Approval files

	Description
Wastes Produced or Received at Site	
Location of waste production	Windsor area, industrial waste from Chrysler, Ford, General Motors, and Hiram Walker
Location of waste disposal	7 hectare area
Waste characterization	domestic and industrial solid wastes
Quantities disposed of	approximately 300 tonnes/day
Period of operation	closed 1973
Waste Containment Facilities	
Method of containment/disposal	controlled landfilling
Surface runoff control	none
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	clay till plain
Site Hydrology	
Drainage basin	Lake St. Clair - Little River
Potential for flooding	none
Potential for surface runoff	moderate
Nearest receiving waters	Lake St. Clair

Table 3.3.4a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	clay overlying clay till
Thickness of overburden	35+ metres
Underlying bedrock deposits	Hamilton Formation shale and limestone
Site Hydrogeology	
Extent of investigations	not documented
Details of shallow ground water flow	northerly to Lake St. Clair
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	waste leachate recharges local watertable
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	none
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff
Current evidence of leachate migration	leachate identified by MOE
Adequacy of surface water quality monitoring	not documented
Adequacy of ground water quality monitoring	not documented

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

1979 found that there are no leachate monitoring or control systems in place at the landfill. Leachate has been identified around the site but not been considered a problem. Any leachate moving off site would likely do so by means of surface run-off.

3.3.5 Site No. E-5. City of Windsor, Malden Road

The Malden Road Landfill operated by the City of Windsor (Certificate of Approval number A010103) has a total area of 73 hectares approved for landfill purposes of which 50 hectares have been completed. The landfill began operating in 1956 and until 1973 it received liquid and solid domestic, commercial and industrial waste, as well as hauled sewage, demolition and excavation materials, trees and brush at a rate of about 500 tons/day. In 1973 the site was closed except for receiving inert material.

Local geology consists of 2 m of sand overlying clay and clay till. Bedrock of the Dundee Formation underlies the clay till at a depth of approximately 30 m. Local topography is described as flat bush land. The water table varies between 0 to 1.2 m below ground surface over the site.

Historically, the Malden Road Landfill has had problems with leachate migration off site. Surface run-off and subsurface seepage of leachate have shown up in McKee Drain that is adjacent to the site and feeds into the Detroit River. Surface water monitoring had been conducted monthly in the past, however no leachate control systems have been implemented at this site. In 1973 the site was closed except for receiving inert material.

Table 3.3.5. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification # E-5
Registration Area: Windsor
Site Certificate Number: 010103
Certificate Holder: City of Windsor
Location: City of Windsor (Malden Road)

Sources of Information: MOE Approval files, OWRC (1968)

	Description
Wastes Produced or Received at Site	
Location of waste production	Windsor area
Location of waste disposal	23 hectares within approved 50 hectare disposal area
Waste characterization	previously domestic and industrial liquids and solids, presently inert material only
Quantities disposed of	approximately 500 tonnes/day
Period of operation	1956 to 1972, closed in 1973 except to inert wastes
Waste Containment Facilities	
Method of containment/disposal	landfilling with soil cover
Surface runoff control	originally uncontrolled
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	sand plain
Site Hydrology	
Drainage basin	Detroit River
Potential for flooding	none
Potential for surface runoff	moderate
Nearest receiving waters	McKee Drain

Table 3.3.5a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	2 m of sands overlying clay and clay till
Thickness of overburden	30+ metres
Underlying bedrock deposits	Dundee Formation limestone
Site Hydrogeology	
Extent of investigations	hydrogeologic study, Golder Associates (1974)
Details of shallow ground water flow	not available
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	poor
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage with possible surface water discharge
Current evidence of leachate migration	previous runoff problems reported extending to Detroit River
Adequacy of surface water quality monitoring	monthly downstream monitoring conducted in the past
Adequacy of ground water quality monitoring	none installed

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.3.6 Site No. E-6. Fighting Island

Fighting Island is a Canadian island located in the Detroit River south of Windsor. The island, however, is owned by the BASF Wyandotte Corporation of Wyandotte, Michigan. By permission of the former Ontario Department of Lands and Forests, BASF has used the island for disposal of manufacturing wastes from its Michigan plant. The disposal took place during 1952 to 1980 throughout approximately 400 hectares (about three-quarters of the island's area). The island originally had very low relief. Its surficial deposits consist of a thin cover of alluvium overlying clay till. The thickness of manufacturing waste deposits presently ranges up to 10 m.

BASF's manufacturing facilities mainly produced soda ash and propylene oxide. The wastes from the soda ash process are easily leachable producing a highly alkaline solution with elevated pH, total dissolved solids, chemical oxygen demand and chloride. These wastes were pipelined to the northern and central settling beds on the island. The oxide production wastes were predominantly calcium chloride residues mixed with calcium carbonate and were piped to the southern settling bed. Some controversy exists concerning the possible presence of trace organic residues within these latter wastes.

The basins extend across the entire width of the island and are surrounded by dykes consisting of rock fill, river sediments and lime residues. The basins include decant ponds that discharge directly into the river. To discourage leachate seepage through the dykes, surface run-off ditches have been constructed behind the dykes. The dykes are inspected semi-annually to ensure their integrity.

Table 3.3.6. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # E-6
Registration Area: Windsor
Site Certificate Number: not applicable
Certificate Holder: not applicable
Location: Fighting Island

Sources of Information: Dames and Moore (1972), Snell (1983), MOE and Environment Canada files

	Description
Wastes Produced or Received at Site	
Location of waste production	manufacturing facilities and BASF, Wyandotte, Michigan
Location of waste disposal	north, south and center settling beds totaling about 400 hectares an island
Waste characterization	alkaline lime residues with elevated COD, chlorides, calcium chloride with trace process chemicals
Quantities disposed of	not documented
Period of operation	north bed (1952 to 1979), centre bed (1926 to 1955), south bed (1964 to 1980)
Waste Containment Facilities	
Method of containment/disposal	island perimeter dykes consisting of rockfill, silt and lime residue
Surface runoff control	natural decant basins to provide clear effluent, dyke seepage control ditches
Leachate collection system	control ditches
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	Detroit River alluvial deposits
Site Hydrology	
Drainage basin	Detroit River
Potential for flooding	low
Potential for surface runoff	controls as noted above are designed to permit off site drainage
Nearest receiving waters	Detroit River

Table 3.3.6a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	organic soils and alluvial sediment overlying clay till
Thickness of overburden	20 to 24 metres
Underlying bedrock deposits	Detroit River Group limestones
Site Hydrogeology	
Extent of investigations	dyke stability and hydrogeologic investigations, residue sampling
Details of shallow ground water flow	outward radial seepage from island, lime residues rise up to 10m above river
Details of deeper ground water flow	not documented
Relationship of waste to flow systems	waste leachates recharge local watertable from residue
Site Geochemistry	
Natural ground water quality characterization	not documented in information reviewed
Leachate quality characterization	residue leachates have elevated pH, TDS, COD, BOD, Cl
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	limited
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	decent basin effluent, discharge from dyke seepage control ditches
Current evidence of leachate migration	MOE sampling of effluents and river sediments found no evidence of heavy metal or organic contaminants
Adequacy of surface water quality monitoring	none
Adequacy of ground water quality monitoring	none required

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Various sampling programs by the MOE and Environment Canada have not indicated a significant impact on water quality or river sediment quality downstream from the island (MOE, 1984). Dilution of seepages or decant pond effluents in the Detroit River is apparently adequate to prevent a quantifiable environmental impact.

3.3.7 Site No. E-7. Gulf and Western

Gulf and Western Canada Ltd. operates a metal plating facility in the City of Windsor. The plant is located on clay till adjacent to Little River which empties into the mouth of the Detroit River. The waste management system at the plant consists of a series of precipitation settling ponds from which sludges are occasionally removed to another storage area. A waste site Certificate of Approval is not required at this particular site. Effluents from the settling pond and plant cooling waters are discharged into Little River.

In 1984, the MOE investigated various problems at this plant related to unacceptable discharges and a release of sludge into the river. Dissolved or leachable constituents of concern in these releases included phenols and several trace elements (chromium, copper, iron, lead, nickel and zinc). Remedial measures at the plant are being supervised by the MOE. Dilution of the plant discharges or any potential plant site subsurface seepage is expected to be adequately diluted in Little River to prevent any effects on Detroit River water quality.

3.4 Algoma District

Within Algoma District two (2) waste sites were considered to pose a threat to the St. Mary's River. The available information from MOE files and consultant reports was examined and summarized.

Table 3.3.7. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # E-7
Registration Area: Windsor
Site Certificate Number: not applicable
Certificate Holder: Gulf and Western Canada Ltd.
Location: City of Windsor UTM

Sources of Information: MOE files

	Description
Wastes Produced or Received at Site	
Location of waste production	manufacturing facilities adjacent to settling and storage ponds
Location of waste disposal	separate settling and storage ponds
Waste characterization	neutralized "plating" solutions, process sludges
Quantities disposed of	not documented
Period of operation	not documented
Waste Containment Facilities	
Method of containment/disposal	storage lagoon
Surface runoff control	perimeter dykes around settling ponds
Leachate collection system	none
On-site treatment facilities	plant effluent neutralization and floculation
Gas control system	none
Physiographic Setting of Site	till plain
Site Hydrology	
Drainage basin	Little River
Potential for flooding	none
Potential for surface runoff	low
Nearest receiving waters	Little River

Table 3.3.7a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	till
Thickness of overburden	approximately 30 m
Underlying bedrock deposits	Dundee or Hamilton Group limestone or shale
Site Hydrogeology	
Extent of investigations	no site studies undertaken
Details of shallow ground water flow	local flow expected towards adjacent river
Details of deeper ground water flow	none
Relationship of waste to flow systems	pond waters and leachate recharge local watertable
Site Geochemistry	
Natural ground water quality characterization	not documented
Leachate quality characterization	not documented
Shallow ground water quality on-site	not documented
Deeper ground water quality on-site	not documented
Attenuation characteristics of on-site deposits	high
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and subsurface seepage
Current evidence of leachate migration	sludge pond overflows and poor quality settling pond effluents documented
Adequacy of surface water quality monitoring	effluent monitoring in effect, poor analytical procedures documented
Adequacy of ground water quality monitoring	none installed

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

3.4.1 Site No. A-1. Algoma Steel Corporation Ltd.

Algoma Steel Corporation operates a large 328 hectare disposal site adjacent to the St. Mary's River, at the West end of Sault Ste. Marie. The site has been in operation since 1910 and presently operates under Certificate of Approval Number A560101. The predominant waste disposed on the site is waste slag from iron and steel operations but quantities of gypsum, industrial refuse, waste acid, waste oil, coke oven gas line condensate and sludge are also disposed on site. Also, lime dust and iron/zinc sludge from the blast furnace gas treatment plant thickener is disposed in the slag dump area. In total approximately 718,600 tonnes of solid waste and 66,800 tonnes of liquid waste are disposed per year.

Disposal operations to present have covered much of the area with a layer of slag 3 to 21 meters in thickness. The slag was placed directly over the natural ground surface and has extended beyond the original shoreline of the peninsula which projected into the St. Mary's River. The slag is underlain by a generally thin stratum of sand with some gravel. Underlying the sand is a layer of clay overlying a layer of silt. In parts of the site the clay layer is absent and the sand stratum directly overlies the silt. Under the clay and silt is a silty sand till which overlies the sandstone bedrock formation.

A detailed hydrogeologic investigation of the site was conducted by Geocon in 1983. A total of 11 boreholes were put down on the site. After completion of each borehole, a plastic standpipe was installed to serve as a ground water monitoring well. Next to boreholes that were completed in the bedrock, a second standpipe was installed so that information could be obtained for both the bedrock and overlying overburden aquifers. Geocon (1983) established that there was a ground

Table 3.4.1. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Idenification # A-1
Registration Area: Sault St. Marie
Site Certificate Number: A560101
Certificate Holder: Algoma Steel Corporation
Location: Sault St. Marie 699650E 5154250N

Sources of Information: Geocon (1983)

	Description
Wastes Produced or Received at Site	
Location of waste production	Algoma Steel Corp.
Location of waste disposal	328 hectares
Waste characterization	predominantly slag, others include gypsum, industrial refuse, waste acid, waste oil, coke oven gas line condensate, iron/zinc sludge, lime dust
Quantities disposed of	718,600 tonnes per year solid, 66,800 m^3 per year liquid
Period of operation	started in 1910, estimated life expectancy of 90 years
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	perimeter ditches
Leachate collection system	none
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	
Site Hydrology	
Drainage basin	St. Mary's River
Potential for flooding	moderate
Potential for surface runoff	moderate, significant compound of precip infiltrations with relatively pervious surface of slag dump
Nearest receiving waters	St. Mary's River

Table 3.4.1a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	glaciolacustrine silts and clays overlying till
Thickness of overburden	122 m @ third line
Underlying bedrock deposits	Jacobsville Formation sandstone
Site Hydrogeology	
Extent of investigations	detailed investigation by Geocon (1983)
Details of shallow ground water flow	ground water mound beneath slag dump
Details of deeper ground water flow	from high ground in north to discharge in St. Mary's River however, this is greatly influenced by pumping in municipal wells
Relationship of waste to flow systems	recharge to local and possibly deep flow system
Site Geochemistry	
Natural ground water quality characterization	MOE water quality analyses of adjacent domestic wells
Leachate quality characterization	analytical results of slag materials and slag pond water
Shallow ground water quality on-site	Geocon (1983) contamination of shallow ground water
Deeper ground water quality on-site	MOE sampling of adjacent domestic wells
Attenuation characteristics of on-site deposits	low
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	surface runoff and ground water seepage
Current evidence of leachate migration	leachate flow evident at base of high slag dump in southwest corner of site
Adequacy of surface water quality monitoring	in effect by MOE
Adequacy of ground water quality monitoring	in effect by MOE and ASC

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

water mound beneath the high part of the slag dump which controlled the local and shallow ground water flow pattern in the area.

The ground water flow was established to be radially outward from the high part of the mound toward the perimeter of the site. On the south side the ground water would ultimately discharge to the St. Mary's River, mainly through the surficial layer of granulated slag fill (permeability of 10^{-3} to 10^{-1} m/s was noted). On the west side of the slag dump, the ground water flow is towards and discharges in a diversion channel which ultimately discharges by surface flow to the St. Mary's River. On the north and northeast sides of the site the local ground water flows are confined by the clay layer (permeabilities of 10^{-9} to 10^{-7} m/s) and therefore subsurface flows tend to be through the slag and sands overlying the clay, ultimately discharging in surface diversion ditches. In the west central part of the slag dump it was determined that the natural soils consist of silty sand to sand and glacial till overlying the sandstone bedrock (permeabilities 10^{-7} to 10^{-5} m/s). Geocon (1983) considered that the ground water mound recharges the till and bedrock strata. The ground water in the bedrock was established to flow from the north to the St. Mary's River. There was some concern that ground water flow from the ground water mound may be northeast towards two Sault Ste. Marie municipal wells. Geocon (1983) felt that it was possible that some minor component of ground water flow exists from the slag dump to the municipal wells, but that travel times of some 200 years were involved.

Water chemistry analyses were carried out and reported by Geocon (1983), however no comments were included in the report. A cursory examination of the data indicate contamination of the

ground water on site. Ministry of the Environment are actively monitoring the site and the wells surrounding the site to establish if the contamination is migrating off site. At present no contaminants have been reported migrating to the north but pollutants have been found migrating into the St. Mary's River.

3.4.2 Site No. A-2. Sault Ste. Marie Landfill (Cherokee) Site

Cherokee Disposal and Construction Ltd. operate an approximately 56.6 hectare site in the northeast end of the City of Sault Ste. Marie. This site is operated under Certificate of Approval number A560102 and serves the city as well as the Township of Prince and the Rankin Indian Reserve. Waste disposed on site are approximately 60% domestic (approximately 200 tonnes/day), 10% commercial (approximately 35 tonnes/day) and 30% sewage sludge (approximately 100 tonnes/day).

An expansion of the landfill to 88.6 hectares has been proposed and as a result a detailed environmental assessment was conducted by M.M. Dillon Ltd. (1984). From these studies the physical setting of the landfill has been determined. The landfill site is underlain, from the surface down, by about 20 m of fine to coarse sand and gravel, 8 m of coarse sand and 13 m of fine to medium sand. Bedrock consist of PreCambrian granite and is found at about 45 m below surface. The landfill site is drained by Canon Creek to the north and west which drains into the Root River to the south.

Gartner-Lee Associates Ltd. (1983) completed a detailed hydrogeologic study including installation of a monitoring well network, geophysical surveys and ground water modeling.

Table 3.4.2. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets (con't)...

GTC Site Identification #: A-2
Registration Area: Algoma District
Site Certificate Number: A560102
Certificate Holder: Cherokee Disposal and Construction Ltd.
Location: Township of Prince
Sources of Information: MOE files, Environmental Assessment, M.M. Dillon Ltd. (1984)

	Description
Wastes Produced or Received at Site	
Location of waste production	City of Sault Ste. Marie, Township of Prince, Rankin Indian Reserve
Location of waste disposal	56.6 hectares, proposed expansion to 88.6 hectares
Waste characterization	200 tonnes/day domestic, 35 tonnes/day commercial, 100 tonnes/day sewage sludge
Quantities disposed of	approximately 335 tonnes/day
Period of operation	
Waste Containment Facilities	
Method of containment/disposal	landfill
Surface runoff control	proposed in environmental assessment for expansion
Leachate collection system	proposed in environmental assessment for expansion
On-site treatment facilities	none
Gas control system	none
Physiographic Setting of Site	
Site Hydrology	
Drainage basin	Root River/Canon Creek
Potential for flooding	low
Potential for surface runoff	low due to high infiltration rate
Nearest receiving waters	Canon Creek, Root River

Table 3.4.2a. Upper Great Lakes Connecting Channels Study Waste Disposal Site Inventory

Summary Sheets

Site Geology	Description
Surficial geologic deposits	fine to coarse gravel
Thickness of overburden	approximately 45 m
Underlying bedrock deposits	PreCambrian Granite
Site Hydrogeology	
Extent of investigations	detailed environmental assessment
Details of shallow ground water flow	well documented Gartner-Lee Associates (1983)
Details of deeper ground water flow	well documented Gartner-Lee Associates (1983)
Relationship of waste to flow systems	recharge to local flow system
Site Geochemistry	
Natural ground water quality characterization	well documented Gartner-Lee Associates (1983)
Leachate quality characterization	well documented Gartner-Lee Associates (1983)
Shallow ground water quality on-site	well documented Gartner-Lee Associates (1983)
Deeper ground water quality on-site	well docuemnted Gartner-Lee Associates (1983)
Attenuation characteristics of on-site deposits	low
Current Status and Monitoring at Site	
Most likely pathway for leachate movement off-site	subsurface seepage
Current evidence of leachate migration	leachate plume identified
Adequacy of surface water quality monitoring	adequate
Adequacy of ground water quality monitoring	adequate

(1) site specific data, (2) regional study information, (3) estimate using generally representative data

Hydraulic conductivities of subsurface materials vary from 3×10^{-7} to 1×10^{-4} m/s and shallow ground water flow is from north to south. In the northernmost portion of the site infiltrating ground water recharges the deeper stratigraphic units and in the centre of the site horizontal shallow ground water flow occurs.

A ground water monitoring network has been installed around the site and ground water chemistry has been determined. A leachate plume south of the site flowing towards Root River was identified. The proposed expansion of the landfill includes a leachate collection system to address the leachate plume.

3.5 Other Sites

In 1979 the Ministry of the Environment carried out a survey and prepared a master list of waste disposal sites in operation prior to 1971. Subsequently, a list was developed of sites that the MOE felt required a more detailed investigation. In 1980 Conestoga-Rovers and Associates (CRA) was commissioned by the Ministry of the Environment to conduct a preliminary investigation into these sites in the southwestern region of Ontario. The sites that fall within the study area are listed in Table 3.5.1.

If a potential problem existed, follow up studies were conducted. The results of the preliminary study and any follow up studies are summarized in Table 3.5.1.

The results indicate that there is little potential contamination problem from these sites with one exception. Site 2063 Chatham, was reported to contain organic wastes. A site investigation by the UMA Group to confirm this, was significantly restricted due

Table 3.5.1 1980 Waste Site Identification Study Site Summaries

	Consultants (CRA) Recommendations	MOE Comments	Current Status
5097 - Town of Amherstburg, Shopping Mall	No recommendations	No further action	No further action
A2 - Town of Amherstburg, Funeral Home	No recommendations	Fill was clean earth	No further action
6066 - City of Windsor, Ford Engine Complex	No recommendations	No further action	No further action
5120 - City of Sarnia, Copland Road	No recommendations	No further action	No further action
5118 - City of Sarnia, Newton Park	Further gas monitoring	City advised	Monitoring of basements by City Fire Dep't., subsequently determined there was no problem
5116 - City of Sarnia, Agincourt Park & Len Park	Further gas monitoring	City advised	Installed gas well & vent system as per design by Conestoga-Rovers, Waterloo
2063 - City of Chatham, Brick Yard	No recommendations	To be investigated further, City advised	Underwood, McLellan Ltd. retained by MOE. UMA recommended further investigations due to inconclusive results
2066 - City of Chatham, Domtar	Further gas monitoring	City advised	Industry advised
2062 - City of Chatham, International Harvester	Further gas monitoring	City advised	Report by McLaren, Engineering etc. London recommended no further action
2065- City of Chatham, Water St. Park	Application of soil cover to reduce hazard of broken glass and metal	City advised	No further action
2060 - Town of Tilburg, Odette Court	Further gas monitoring	Town advised	No further action
2047 - Town of Essex, Forest Ave.	Further gas monitoring	Town advised	Heath Survey Consultants Ltd., London retained by Town to do further monitoring subsequently recommended no further action
A1 - Township of Malden, west side Hwy. 18	No recommendations	No further action	No further action

to stringent owner-defined controls as to areas open to field investigations. The results were inconclusive and further investigations were recommended.

Table 3.5.2 is a list of waste disposal sites within the study area that do not have Certificates of Approval and are therefore assumed to be closed sites. The locations of these sites are illustrated on Maps 071-03-E (Essex County), 071-03-K (Kent County) and 071-03-L (Lampton County). Very little information was available for these sites and, therefore, definitive site descriptions were not compiled. In general, it is felt that the contamination potential of these sites is minimal and they are not expected to significantly impact the receiving water courses of the study area. However, because very little is known about these sites, further comprehensive investigations may have to be undertaken to confirm the above.

In addition to those sites listed in Tables 3.5.1 and 3.5.2, a number of sites were closed in the period of 1971 to 1985. In 1971, the Certificate of Approval system was implemented and records were kept for each waste site with a Certificate of Approval. Table 3.5.3 presents closed waste sites with cancelled or revoked Certificate of Approvals. The approximate locations of the sites listed in Table 3.5.3 are given on Maps 071-03-E (Essex County), 071-03-K (Kent County) and 071-03-L (Lambton County). Very little information was available for most of these sites.

These sites tend to be small, local sites used primarily for domestic or commercial wastes but several sites (i.e., Ford Motor Co. W 42, Sun Oil Co. Ltd. W 51, Fiberglass Canada Ltd. W 52, and Dupont of Canada Ltd. W 55) contain industrial waste. Except for the industrial waste sites, most of these sites are not of

Table 3.5.2 Waste Disposal Sites Without Certificate of Approval and Definitive Site Descriptions

GTC#	SITE NAME	LOCATIONS
W 1	Moore Township	East of intersection of Main & 8th Street in Courtright
W 2	Point Edward	Kendall Street
W 3	Point Edward	Corner of Christina St. and Michigan Avenue
W 4	Sarnia (City & Twp)	Lot 15, Concession 4
W 5	Sarnia (Twp)	South side of Cathcart Parkland Place Subdivision
W 6	Sarnia (Twp)	North side of Cathcart
W 7	Dow (Vidal St)	Lot 27, River Range City of Sarnia
W 8	IOL (Sludge Farm)	Lot 10, Range 11, City of Sarnia
W 9	Sarnia Landfill	City of Sarnia, Bounded by Cathcart Blvd., Sarnia Rd. Lite Street, Sarnia Golf Course
W 10	Twin Lakes	Lots 51-54, Concession 9, Sarnia Township
W 11	Ladney	Lot 26, Concession 11, Moore Township
W 12	Wilkesport	Lot 11 (N½), Concession 7, Sombra Township
W 13	Maidstone Twp	East of West Pike Creek Road, south of CN Tracks
W 14	City of Windsor	Giles Blvd. east of Ouellette Ave.
W 15	City of Windsor	South side of Riverside Drive from Dieppe to east of city limits
W 16	City of Windsor	River from north of Russell at foot of Watkins & South Streets
W 17	City of Windsor	Little River Road east of Riverdale

Table 3.5.2 Waste Disposal Sites Without Certificate of Approval and Definitive Site Descriptions (cont'd)

GTC#	SITE NAME	LOCATIONS
W 18	City of Windsor	Russell Street at Detroit Ave.
W 19	City of Windsor	McKee Road & Sandwich road
W 20	City of Windsor	Charles Boulevard
W 21	City of Windsor	North of Riverside Drive, across from Lido Tavern
W 22	City of Windsor	Transfer Stastion E. C. Row
W 23	City of Windsor	Compost site west Windsor Pollution Control Plant
W 24	Village of St. Clair Beach	Manning road & St. Gregory's Rd. NW corner
W 25	Sandwich South Twp	NE¼ Lots 299-303 south of Hwy. 3
W 26	Sandwich South Twp	West of Shawnee Rd. S of Hwy. 2
W 27	Town of Amherstburg	Sandwich & Pickering Street - west of Fort Malden Mall located on Hwy. 18 South
W 28	Town of Amherstburg	Bailey's Creek (Bailey's Subdivision) immediately south of Amherstburg west side of Hwy. 18
W 29	Town of Tecumseh	East end of Clarice Blvd.
W 30	Sandwich West Twp	Lots 3 & 4, Plan 1010, Dave Dufoursite
W 31	Sandwich West Twp	Malden Rd. & Normandy St. (Brunet Park)
W 32	Malden Twp	West side of Hwy. 18 at Concession 3 Road
W 33	Malden Twp	Lot 19, Front Concession
W 34	Tilbury North Twp	Lot 21, Concession 6

Table 3.5.2 Waste Disposal Sites Without Certificate of Approval and Definitive Site Descriptions (cont'd)

GTC#	SITE NAME	LOCATIONS
W 35	Tilbury North Twp	Lot 21, Concession 2
W 36	Town of Belle River	End of St. Peter St. north of CPR Tracks
W 37	Anderdon Twp	SE Corner Lot 14, Concession 4
W 38	Anderdon Twp	NW Corner Lot 14, Concession 4
W 39	Anderdon Twp	North half Lot 6, Concession 3
W 40	Sandwich West	Senator and Wahketa Streets
W 41	Windsor	South end of Virginia Ave.

Table 3.5.3 Closed Sites with Cancelled or Revoked Certificates of Approval

GTC No.	Certificate of Approval [a]	Site Name	Location	Area (hectares)	Type of Waste	Volume tonnes/day	Duration of Operation[b]
W 42	010108	Ford Motor Co.	Lots 118, 119, 120, Con. 11, City of Windsor	25	Hauled Liquid Industrial Waste	N/A	1974-79
W 43	021202	Village of Wheatley	-	0.8	Domestic, Commercial	1	1974
W 44	021306	Town of Dresden	Pt. Lot 4, Con. 3 Twp. of Camden	2	Domestic, Commercial	6	1971-74
W 45	021401	Twp. of Chatham	Lot 7, Con. 3 Twp. of Chatham	2	Domestic, Commercial, Agricultural	8-10	1971-79
W 46	020701	Town of Wallaceburg	Baldoon Rd. and Libby St.	5	Domestic & Industrial	29	1971-74
W 47	021501	Twp. of Dover	Lot 1, Con. 8 Twp. of Dover	3	Unknown	N/A	1971-74
W 48	021901	City of Chatham	Lot 13, Con. 4 Twp. of Raleigh	6	Agricultural, Other	10	1972-74
W 49	021902	Twp. of Raleigh	Lot 7, Con. 8 Twp. of Raleigh	2	Domestic, Commercial	5	1971-74
W 50	022103	City of Chatham	Lot 1 & 2, Con. 8 Twp. of Tilbury East	Unknown	Domestic	N/A	1972-81
W 51	030101	Sun Oil Co. Ltd.	Lot 17, River Range Twp. of Sarnia	0.009	Industrial	0.7	1973-79
W 52	030102	Fiberglass Canada Ltd.	Scott Rd., Sarnia	4	Industrial	30	1972-75
W 53	030801	Village of Oil Springs	Pt. Lot 18 & 19, Plan 3 Village of Oil Spring	0.4	Domestic, Commercial	0.8	1971-76
W 54	031501	Twp. of Dawn	Pt. Lot 22, Con. 14	0.8	Domestic	0.3	1971-75
W 55	031803	Dupont of Canada Ltd.	Lot 26, 27, Con. 2 Moore Twp.	1.4	Industrial	1.5	1971-76

Notes:
a) Certificates of Approval for these sites have been cancelled or revoked.
b) In most cases, the duration of operation is indicated as starting in 1971 but this is indicative of the start of the Certificate of Approval system and some sites may have been in use prior to 1971.
N/A Indicates volumes are not available.

concern with regards to environmental impact. Due to lack of information, definitive site descriptions have not been prepared for these sites.

Several small active federal waste sites, controlled by Environment Canada, are also found within the Sarnia-Windsor study area. These sites are listed as follows:

- Essex County - Windsor Agricultural Station;
- Lambton County - Sarnia Indian Bond;
  - Point Edward/Canadian National Railway Station;
  - Sarnia Agricultural Station;
  - Harrow Agricultural Station.

None of these sites are listed in Environment Canada's Waste Site Inventory nor are they included in their Waste Site Scoring Summary. Because of small size and the innoxious quality of the waste, these sites are not considered to represent an environmental problem.

From the sites listed in Tables 3.5.1, 3.5.2 and 3.5.3, several sites are likely to be of concern with regards to potential environmental impact on the Detroit or St. Clair Rivers due to the type of wastes disposed or proximity to the major waterways. These sites are listed as follows:

- Site No. W 11, Ladney - Lot 26, Concession 11, Moore Township;

- Site No. W 16, City of Windsor - River front north of Russell at the foot of Watkins and South Streets;

- Site No. W 42, Ford Motor Co. - Lots 118, 119, 120, Concession 11, City of Windsor;
- Site No. W 51, Sun Oil Co. Ltd. - Lot 17, River Range, Township of Sarnia;
- Site No. W 52, Fiberglass Canada Ltd. - Scott Road, Sarnia;
- Site No. W 55, Dupont of Canada Ltd. - Lots 26, 27, Concession 2, Moore Township.

The potential for environmental impact from these sites is largely unknown at this time.

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APPENDIX 1

Storm Hydrographs

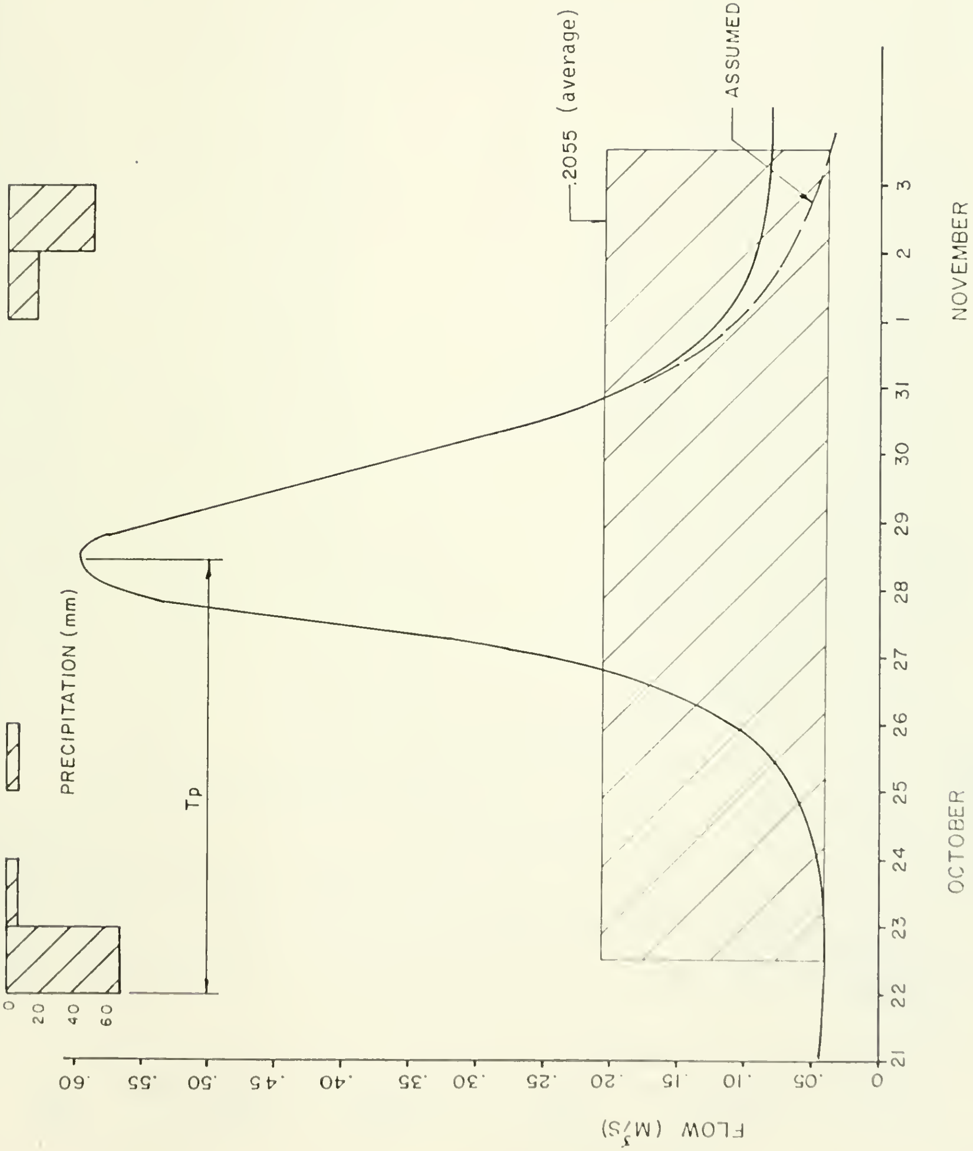

Figure A1.1 Storm Hydrograph, Bear Creek, 1983

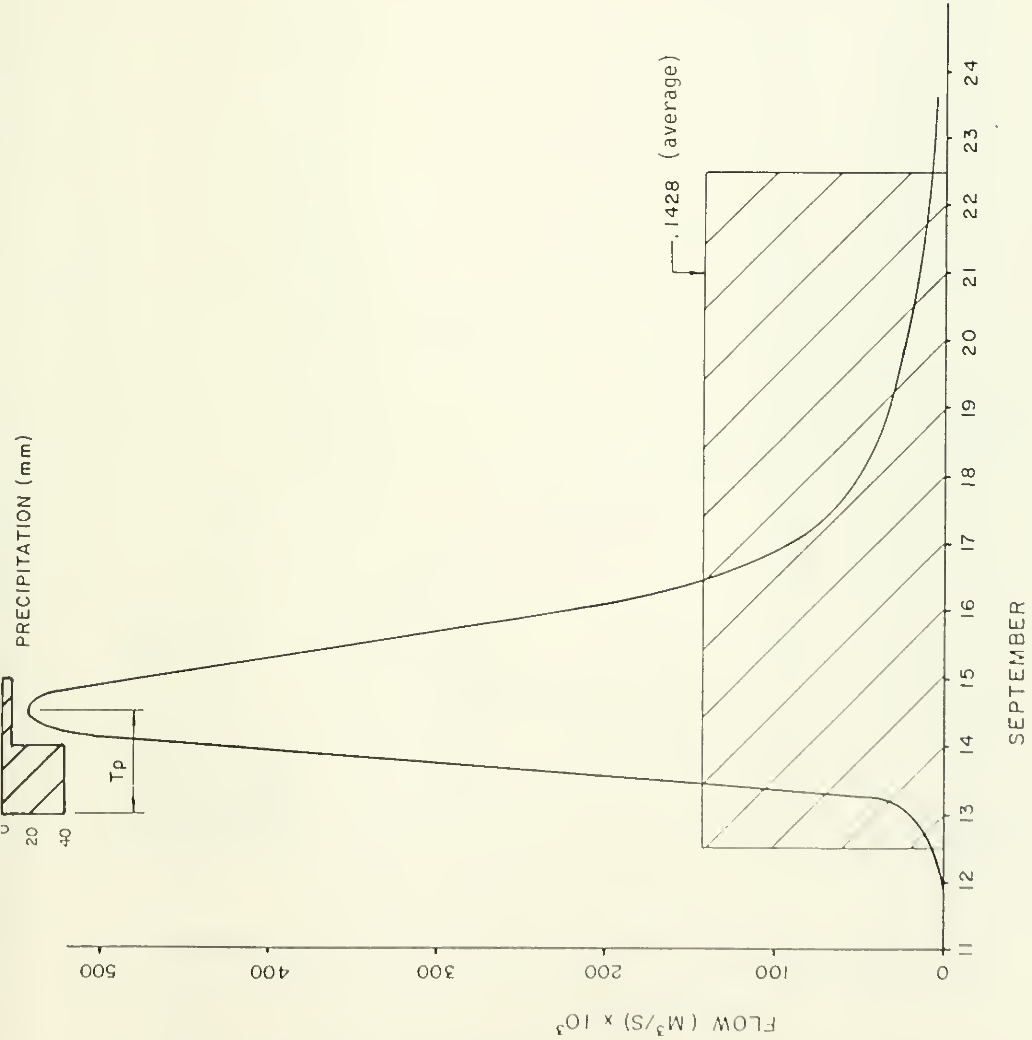

Figure A1.2 Storm Hydrograph, Canard River, 1979

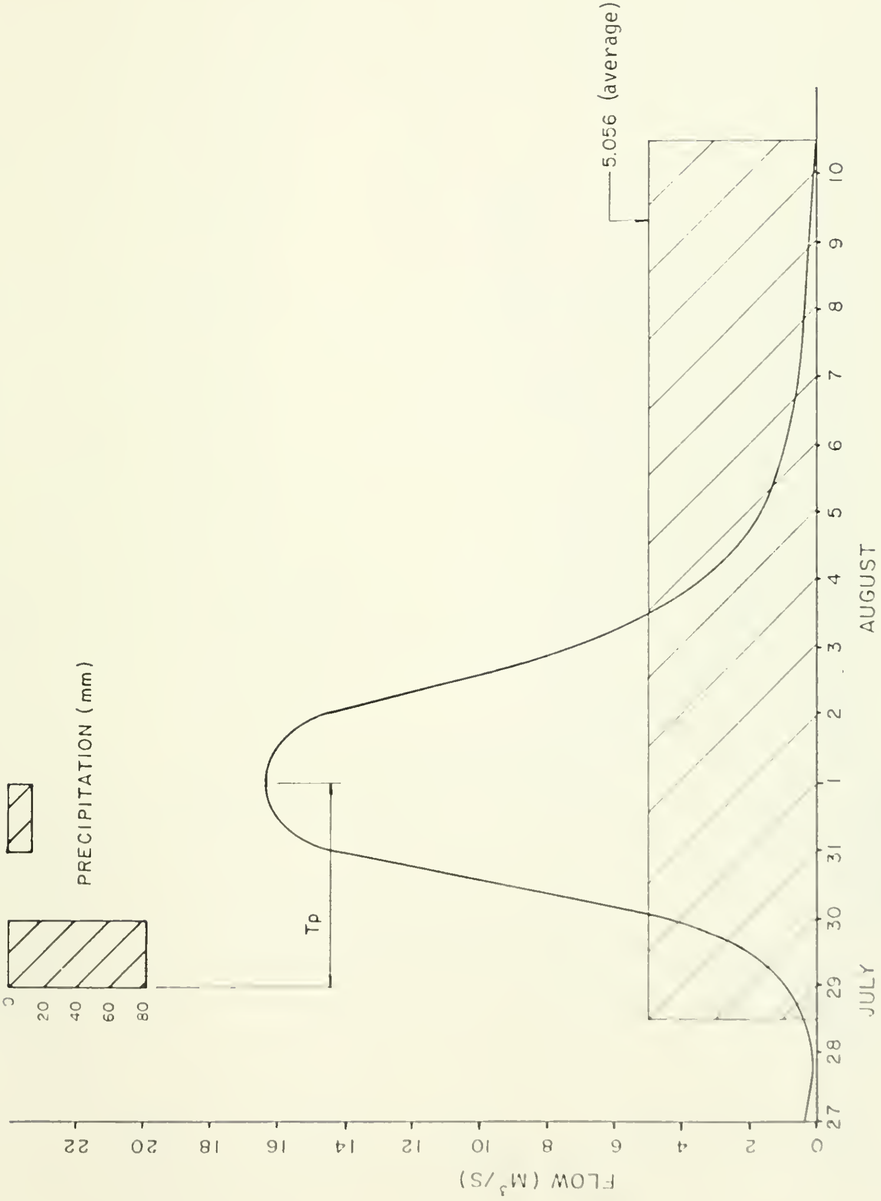

Figure A1.3 Storm Hydrograph, Canard River, 1983

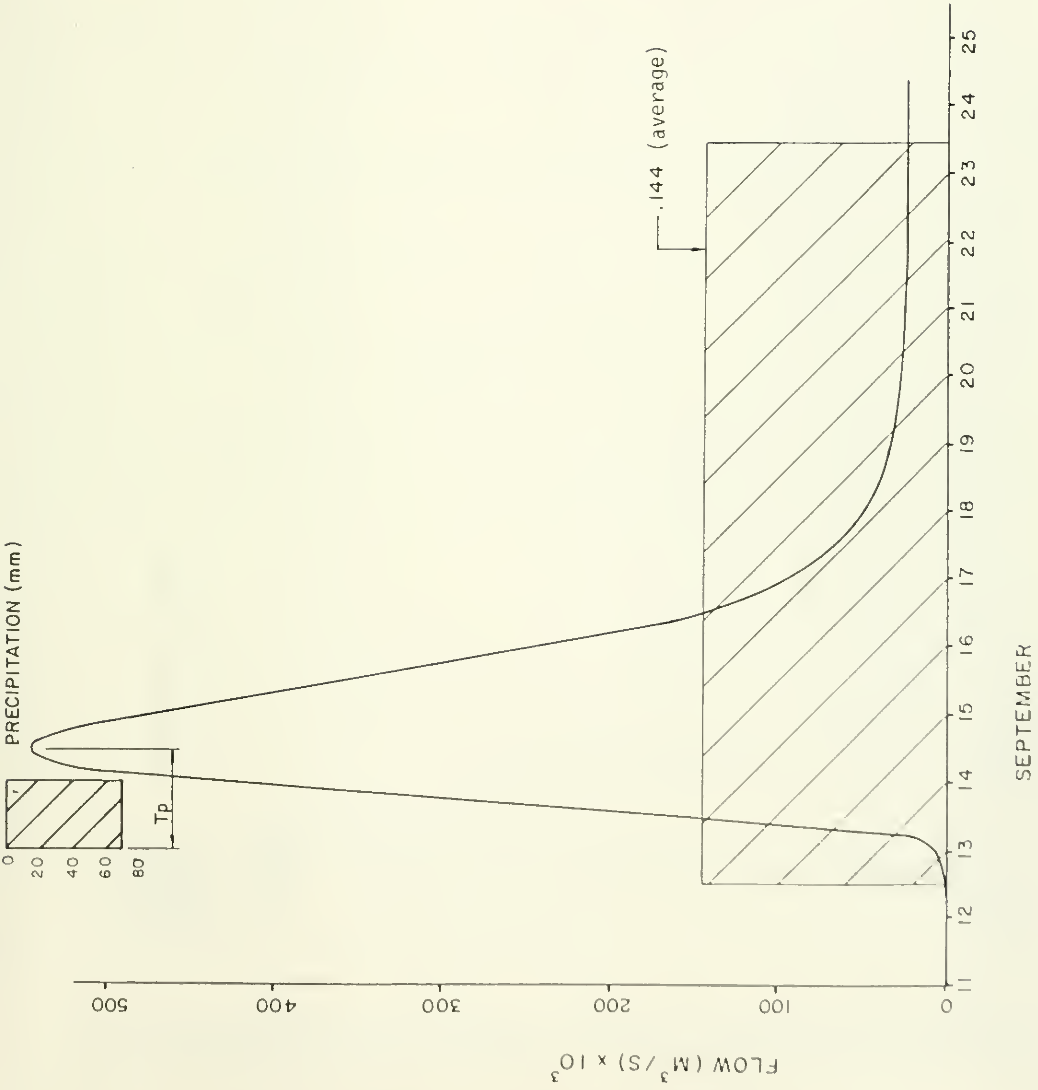

Figure A1.4 Storm Hydrograph, Rescom River, 1979

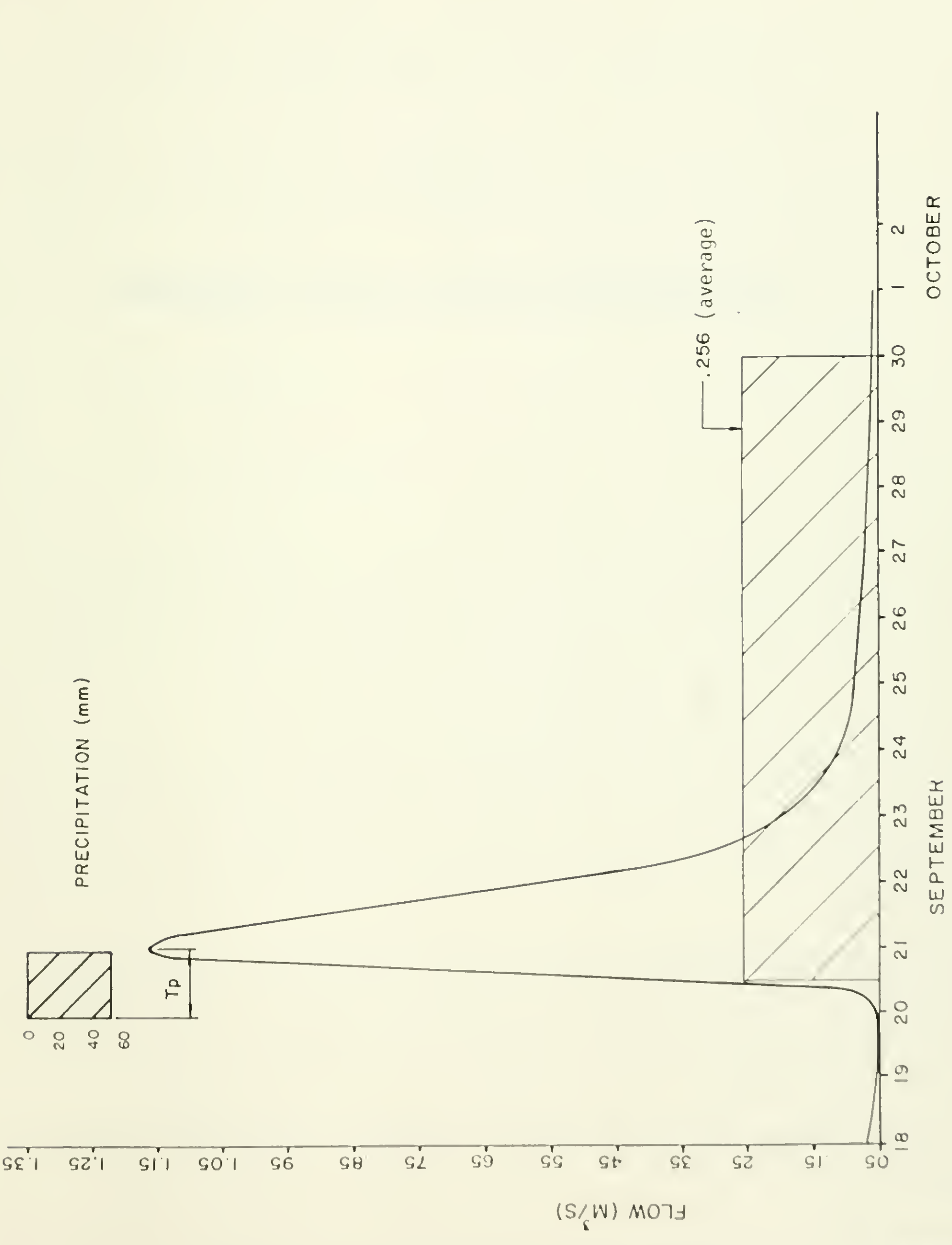

Figure A1.5 Storm Hydrograph, Ruscom River, 1983

APPENDIX 2

Contaminant Transport and Attenuation Mechanisms

A2.0 Contaminant Transport and Attenuation Mechanisms

The theoretical basis for advection and dispersion including molecular diffusion will be described in this section. Implications for field detection and monitoring of contaminant plumes within the study area will be discussed. The second part of this section will outline the attenuation mechanisms that are thought to impede or retard the movement of contaminants in ground water. The significance of these factors in assessing the impact of ground water contamination on receiving waters will also be addressed.

A2.1 Contaminant Transport

In the transport of contaminants by ground water, advection describes the process by which solutes are transported by the bulk motion of the flowing ground water while molecular diffusion occurs in response to concentration gradients. Diffusive flow is directed from areas of high solute concentrations to areas of low concentrations. During advective flow, drag forces caused by the walls of individual grain capillaries and the tortuous path of flow causes the solute to be spread out in the direction of and normal to the direction of flow. This spreading is referred to as dispersion and results in dilution of the solute.

To mathematically describe the transport of contaminants in ground water, it is first necessary to consider the conservation of mass for an elemental volume of porous media and to recognize the physical processes that control the flux of a contaminant into or out of this volume and the loss or gain of mass within the volume. Advection and dispersion are

responsible for the input and output of the volume while the loss or gains could be caused by chemical or biochemical reactions or radioactive decay.

The one-dimensional form of the advection-dispersion equation for unretarded dissolved contaminants in a saturated homogeneous, isotropic medium under steady-state, uniform flow is given by:

$$D_x \frac{\delta^2 C}{\delta x^2} - V \frac{\delta C}{\delta x} = \frac{\delta C}{\delta t} \qquad \text{(A2.1)}$$

where x = linear distance along the flow line;
V = average linear ground water velocity;
D_x = coefficient of hydrodynamic dispersion in the x-direction;
C = concentration of the unretarded contamination;
t = time.

The coefficient of dispersion (in the direction of flow, x) is dependent on the ground water velocity and molecular diffusion according to the following:

$$D_x = \alpha_x V + D^* \qquad \text{(A2.2)}$$

where α_x = dispersivity (characteristic mixing length for the porous media);
D^* = coefficient of molecular diffusion.

The one-dimensional steady state advection-dispersion equation can be solved for the following boundary conditions: the concentration of the solute in the porous media is everywhere

equal to zero at time equal zero; the input concentration of the contaminant is equal to Co; and the concentration of the contaminant at large distances from the source is equal to zero at all times greater than zero; to yield the following analytical solution:

$$\frac{C}{Co} = \frac{1}{2}\left[\operatorname{erfc}\left(\frac{x-Vt}{2\sqrt{D_x t}}\right) + \exp\left(\frac{Vx}{D_x}\right)\operatorname{erfc}\left(\frac{x+Vt}{2\sqrt{D_x t}}\right)\right] \quad \text{(A2.3)}$$

where erfc is the complimentary error function.

Therefore assuming that the median concentration (C/Co = 0.5) of the contaminant moves with the ground water velocity it is possible to predict the travel distance of the contaminant for a given time period. Although this sounds relatively simple, in actual fact the prediction of contaminant migration rates is complicated by three-dimensional components of velocity, dispersivity, hydraulic conductivity and hydraulic gradient in natural systems. More detailed discussions of the theoretical basis for contaminant transport due to advection and dispersion is given in many textbooks including Bear (1979) or Freeze and Cherry (1979).

While advection and dispersion are the dominant transport mechanisms in sands and silts, diffusion will be responsible for the migration of contaminants in fine grained materials such as clays. Diffusion is the process whereby contaminants move in the direction of a concentration gradient. Where ground water velocities are small and mechanical dispersion is negligible, the one-dimensional steady-state solution for a saturated porous media given above reduces to Fick's second law. Fick's second law describes the concentration of a

diffusing substance in space and time and is given by

$$\frac{\delta C}{\delta t} = D^{*} \frac{\delta^{2} C}{\delta x^{2}} \qquad (A2.4)$$

where D^{*} is the apparent diffusion coefficient and its one-dimensional analytical solution for an initial concentration of Co is given by

$$\frac{C}{Co} = \mathrm{erfc}\left(\frac{x}{2\sqrt{D^{*}t}}\right) \qquad (A2.5)$$

The apparent diffusion coefficient for a nonadsorbed species in porous media is dependent on the diffusion coefficient and the porosity of the formation. To determine the transport of a solute by diffusion the one-dimensional form of Ficks first law can be used as follows:

$$F = - D \frac{dC}{dx} \qquad (A2.6)$$

where F = mass flux; mass of solute per unit area per unit time; and

$\frac{dC}{dx}$ = the concentration gradient.

The transport of a solute species is therefore dependent on the diffusion coefficient. In aqueous solutions, the major ions (Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, HCO_3^{-} and SO_4^{2-}) have coefficients in the range 1 to 2×10^{-5} cm^{2}/s at 25°C (Robinson and Stokes, 1965). At lower temperatures the diffusion coefficients are smaller. In porous media, due to the effect of the solid phase on diffusion, the coefficients are reduced. Representative diffusion coefficients for the clay materials in the

Sarnia-Windsor area are given in Table A2.1.1. For coarser-grained materials the coefficients are somewhat higher but less than those of the same species in water.

Using the one-dimensional analytical solution for Fick's second law, a typical diffusion coefficient of 3×10^{-6} cm^2/s and a period of diffusion of about 30 years (i.e., typical for a landfill in the Sarnia-Windsor area), a travel distance on the order of one metre can be calculated for the leading edge (defined by $C/Co = 0.01Co$) of a diffusing plume. When compared to the average ground water velocities which are significantly smaller for the same material the diffusive velocities are relatively large. The consequence of this fact in terms of contaminant migration in low permeability material is described in the next section.

A2.2 Contaminant Transport Implications

In the study areas, the transport of contaminants is dependent on the physical hydrogeology of the thick clay sequences that overlie the more permeable bedrock. It is important to note the significance of these clay sequences with regards to subsurface waste disposal and the potential for off-site migration by contaminant transport. For the purposes of this discussion, it is assumed that both regions (Sarnia-Windsor and Algoma) are dominated by the clay sequences, although in the Algoma District the clay is occasionally interlayered with silt and is found in depressions between the sandstone bedrock. In the Algoma District sand and gravel aquifers are also found north of the St. Mary's River at the contact with the crystalline basement bedrock.

Table A2.1.1 Representative Diffusion Coefficient

Source	Location	Diffusing Substance	Diffusion Coefficient cm^2/s
Goodall and Quigley, 1977	Sarnia Blackwell Road	Mg	19.0×10^{-7}
		K	6.4×10^{-7}
		Na	10.0×10^{-7}
		Ca	2.7×10^{-7}
	Sarnia Confederation Road	Mg	13.6×10^{-7}
		K	4.8×10^{-7}
		Na	3.4×10^{-7}
		Ca	2.2×10^{-7}
Crooks and Quigley, 1984		Na	2.5×10^{-6}
		Cl	6.0×10^{-6}
Hydrology Consulants, 1984	Tricil	^{36}Cl	$5.6 - 6.4 \times 10^{-6}$
		^{3}H	$5.6 - 6.8 \times 10^{-6}$
		Phenol	4.0×10^{-6}
Desaulnier et al., 1981	Windsor-Sarnia area	^{18}O	3.0×10^{-6}
		^{2}H	3.0×10^{-6}
		Cl	3.0 x 10-6

The clay sequences, especially in the Sarnia-Windsor area are noted to be of low permeability and have very low ground water velocities. The upper regions of the clay are likely to be weathered and/or fractured. Hydraulic gradients in this material are directed downwards towards more permeable material (sands and sandstone for the Algoma District and sand and fractured shale for the Sarnia-Windsor area) as well as horizontal towards local streams and ditches.

With this information in hand, it is now possible to examine the fate of contaminants that may be produced from a waste disposal site situated on the clay material.

As precipitation infiltrates the waste pile of a disposal site it produces a leachate of variable composition. The leachate then continues in the direction of the hydraulic gradient either as surface run-off or infiltration to the water table. If one assumes that the water table is located in the weathered zone of the clay, contaminant transport will occur vertically and horizontally. Horizontal flow towards ditches, creeks and rivers will likely dominate over vertical flow due to the lower permeability of the underlying intact clays. It is then necessary to examine the transport processes that occur in the weathered zone of the clay.

In this zone, it is likely that it has increased permeability due to fracturing and the leaching of clay minerals. Fractures because of their open apertures will be the major conduit of contaminant transport. It has been noted that the ground water velocities in the fractures will be higher than in the intact media and therefore, if the fractures are connected, significant contamination can be found at greater distances from the landfill due to fracture flow. The contaminant flux from these fractures, however, will be low because of the limited volumetric flux through the narrow

fractures. However, in the case of some wastes, even a small flux of a hazardous material may be significant in terms of an environmental impact on a surface water body. Fortunately, there are physical processes that may reduce or retard the contaminant flux.

In fractured clays, diffusion plays an important role in reducing the contaminant flux from a landfill. While contamination is migrating as a dissolved constituent via a fracture, it is also subject to diffusion from the fracture and into the matrix. Because the matrix has a larger pore volume as compared to the fracture it is possible to retard the migration of dissolved contaminants by this diffusive process. Under two phase transport conditions, although it is unlikely that a second phase will enter the matrix pore space without first overcoming the 'entry pressure' requirements (see following section), dissolved constituents at the liquid/liquid interface will continue to be retarded via matrix diffusion.

In the intact clays, the diffusion process is the dominant contaminant transport mechanism. With very low ground water velocities, if a contaminant is to leave a waste disposal site via the ground water, it will occur by diffusion. In this case, it is important to note the consequence of the driving force namely the concentration gradient. This force will be directed from high concentration to low concentration and therefore may occur in any direction (providing the ground water velocity is negligible). For waste disposal, trenches placed into the clay will be subject to this process. Consequently, clay capped waste trenches are not completely contained from the environment and upward and lateral diffusion will occur as readily as downward. Although the process is slow, it is conceivable that significant contaminant transport will result from diffusion, and waste disposal sites placed in or on clay soils could have an adverse environmental impact on surface and ground water.

A2.3 Two Phase Flow and Transport

Under conditions of a concentrated liquid input to a waste site, or decay and generation of a nonaqueous phase (NAPL) liquid/microbial product, there is the likelihood of developing a NAPL phase at virtually every waste site. NAPL's may have various properties, however in the context of chemical wastes and chlorinated organics, most of the potential NAPL's are denser and less viscous than water (although this is not exclusively the case). Consequently, most NAPL's will tend to migrate downward, under density gradients and preferentially to water (due to their lower viscosity) providing, however, that conditions for liquid-liquid phase displacement have been met.

In order for a second phase to enter a pore space (or fracture) and displace a previously existing phase, the liquid-liquid and solid-liquid surface tension forces must be overcome. The minimum force required to displace the first liquid is referred to as the 'entry' pressure. The entry pressure is dependent on a number of fluid and medium-related factors, including the in-situ pressure of the previously existing fluid. With density dominated vertical flow the 'usual' case in the study areas, the primary factors on which the entry pressure are dependent are the fluids densities and viscosities and the pore size (and hence the liquid/solid surface tension forces).

If the 'entry' pressure for NAPL is exceeded, downward migration rates of NAPL through either fractures in tills and clays or through the intergranular pore spaces, are essentially determined by the density of the fluid and the permeability of the medium to NAPL. Under fractured conditions, the downward migration rates of relatively high density NAPL can conceivably be quite high.

A2.4 Attenuation Mechanisms

The two major geochemical processes by which chemical ions in solution are retarded in their movement with respect to the flowing ground water are adsorption and precipitation.

A2.4.1 Adsorption

Adsorption in simple terms, is the process by which ions in solution are attracted to the surface of colloidal particles by chemical and electrical forces. Adsorption is customarily divided into two broad classes, namely physical adsorption and chemisorption.

Physical adsorption equilibrium is very rapid in attainment and is reversible, the adsorbate being removed without change by reducing the chemical potential (ie. reversing the chemical driving force). The potential determining ions are adsorbed onto the surface by hydrogen bonds and van der Waals attraction forces. Physical adsorption involves energies of interaction in the order of 4000 - 40,000 J/mole.

Chemisorption may be rapid or slow and the energy of adsorption is large enough to suggest that full chemical bonding has occurred (ie. irreversible unless energy is supplied). The potential-determining ions are adsorbed to the surface by chemical bonds (ionic and/or covalent). Chemisorption involves energies of interaction in the order of 125 - 210 x 10^3 J/mole (Hamaker and Thompson, 1972).

Because colloids play such an important role in the retardation of chemicals in ground water some detail will be provided about these particles. Basically, colloids range in size from 10^{-3} mm to 10^{-6} mm. Most clay size particles fall within this range (2 x 10^{-3} mm).

The physico-chemical properties of clay particles are a function of the electrostatically unbalanced charges along the surfaces and edges of the crystal. Because of the very high surface area of these particles, clay particles possess a significantly large chemically reactive surface area that results in colloidal particles playing an important role in the attenuation of chemical migration by adsorption.

A measure of the unbalanced surface charge that is useful to quantify the attenuating ability of soil is the cation exchange capacity (CEC). This property is defined as the excess of counterions in the double layer which can be exchanged for other cations in a negative double layer system (von Olphen, 1963).

Clays can also behave like an ion exchanger replacing an adsorbed counterion with another that has momentary preference at the exchange site. This property is measured by the selectivity quotient and the distribution coeficient. This second term is more widely used in hydrogeological parlance and is defined as the "number of millequivalents of an ion adsorbed per gram of exchanger divided by the number of millequivalents of that ion per millilitre remaining in solution at equilibrium" (Amphlett, 1964).

In the Sarnia-Windsor area representative cation exchange capacities have been measured at a number of locations and are given in Table A2.4.1. The cation exchange capacities typically range from 5 to 40 meq/100 g. These values are relatively low as compared to other clays (e.g., smectites and vermiculites) but represent significant retardation potential. The CEC is at a maximum near the surface in the Sarnia area and decreases with depth. This fact is likely

Table A2.4.1 Representative Cation Exchange Capacities

Source	Location	Cation Exchange Capacity meq/100g
Hydrology Consultants, 1984	Tricil	12.7 - 13.5
Gartner Lee Assoc. 1983	Ridge Landfill	5.6 - 12.5
Quigley & Oqunbadejo, 1976	Sarnia	5 - 40
MacLaren Plansearch, 1982	Shell, Corunna	9.8 - 18

due to the weathering of the clay minerals in the shallow surface. The dominant clay mineral (approximately 20 - 25%) in the Sarnia-Windsor clays and tills is illite which has a typical CEC of 10 - 40 meq/100 g. The second most prevalent clay mineral is smectite which typically has a CEC of 80 - 150 meq/100 g. In the Sarnia-Windsor area smectite is prevalent near the surface due to the result of weathering but decreases to a small percentage with depth. The illite content also decreases with depth but remains as a dominant clay mineral. The decreasing cation exchange capacity with depth is therefore the result of the change in clay mineral content with depth.

In addition, clay minerals can also adsorb anions (negative) as well as cations (positive ions). This property is measured by the anion exchange capacity. Grim (1968) has shown that the following anion-exchange capacities exist: kaolinite 6-20 meq/100 g; smectite, 23-31 meq/100 g; and vermiculite, 4 meq/100 g.

The presence of hydrous oxides of iron, manganese, aluminum and titanium in soil also control the migration of contaminants in ground water. These substances are referred to as hydroxides, and oxyhydroxides or sesquioxides. Iron and mangenese are the most important hydrous oxides. Because they may exist in various oxidation states depending upon the pH and reduction-oxidation potential of the ground water, their role in contaminant attenuation is more difficult to identify. Amphlett (1968), stated that the cation exchange affinity series for the Group 1 cations on $Mn(OH)_2$ with an exchange capacity of 73 meq/100 gm was identical with that already defined for the clay minerals.

Iron hydroxides have been noted to be present in the weathered zone of the clay tills in the Sarnia-Windsor area by Quigley and Ogumbadejo (1976). Kown and Ewing (1969) have stated that humic substances, found in soils, also play an important role in determining the cation exchange capacity of clays by blocking exchange sites or adjusting the affinity series or causing swelling. The organic matter found in soils and sediments are of two types - humic and non-humic. The humic fraction (resistant to microbial attack) can be separated into three parts:

(1) humic acid - soluble in dilute alkaline solution;
(2) fulvic acid - soluble in acidic and basic solution;
(3) humus - insoluble in both acidic and basic solutions.

Schnitzer and Khon (1972), noted that all humic fractions have the ability to form water-soluble and water-insoluble salts and complexes with metal ions and hydrous oxides. This property gives humic acids and soils significant exchange capacities and retarding ability.

A2.4.2 Precipitation Processes

The second major mechanism for attenuating the transport of contaminants is by precipitation - either direct precipitation by chemical complexing or by isomorphous substitution.

A2.4.2.1 Direct Precipitation

This mechanism is characterized by an equilibrium established between the chemical in solution and the solid phases. This equilibirum is described by an ion-activity solubility (K_{SO}) product and is empirically derived.

The solubility products values are a function of pH and redox potential as described by the Eh - pH diagrams that outline the geochemical reactions for different environments of the various geochemical species (Berner, 1971 and Domenico, 1972).

Solubility products also depend on temperature but are relatively independent of the concentration of the various ions provided the solution is rather dilute. Hydroxides typically have very low solubility product values (Keq $Fe(OH)_3 = 10^{-40}$ whereas sulphates have much larger values (Keq $Ca(SO_4) = 10^{-5}$). Ions such as iron would be relatively immobile if they existed in the dissociated state since the preferred state is as a solid precipitate.

A2.4.2.2 Replacement and Coprecipitation

This mechanism is characterized by the isomorphous substitution of one chemical ion for another of similar charge density and ionic radius. The significant feature of replacement and coprecipitation processes is that the new solid phase is more stable in the replacing solution than the original solid phase (Rontson, 1973). This allows for the prediction of the degree of adsorption to be expected from solubility calculations. As a first approximation, this approach has met with limited success (Stumm and Morgan, 1970).

Finally the presence of nucleation sites affects the degree of precipitation and crystal formation in ground water systems. Berner (1971) has suggested that nucleation in natural waters is expected to occur on preexisting colloids, such as clay minerals. For hydrous metal oxides

at high degrees of supersaturation, the nucleation rate is so fast that the precipitate consists of very small crystallites marginally larger than the nucleation catalyst.

A2.5 Contaminant Transport with Geochemical Retardation

Transport of solutes in the ground water system is often affected by reaction with the geologic media through which it is moving. Reactions of this nature result in an apparent retardation of the contaminant with respect to the rate of ground water movement. Retardation reactions in the ground water system can be attributed to either one or a combination of the attenuation mechanisms discussed in Section A2.4. Most of these reactions are surface type phenomena while reactions such as hydrophobic bonding represent a phase partitioning and is observed primarily with organic chemicals.

A partitioning of virtually all contaminants between the solid and aqueous phases is usually encountered in ground water systems. This partitioning is described, in its simplest form, by a distribution coefficient which describes the equilibrium ratio of contaminants distributed between the solid and aqueous phases. The processes which the partitioning coefficient describe are known as sorption and desorption. In the context of toxic chemical contamination, sorption would refer to all processes which tend to remove contaminants from the aqueous phase while desorption refers to those processes which solubilize or redissolve (i.e., mobilize) the previously sorbed toxic constituents.

Retardation of a particular chemical species is often described by a retardation factor, R, defined as follows:

$$R = \frac{V_x}{V_A} = 1 + \frac{\rho_b}{n} \cdot K_d$$

where V_x = average linear ground water velocity;
V_a = velocity of the contaminant
ρ_b = bulk density of the porous media;
n = porosity of the porous media;
K_d = partitioning or distribution coefficient.

This equation is quite useful in ground water and contaminant transport studies provided it is used with a knowledge of its limitations. The main limitations arise from the definition of the parameter K_d which represents the slope of the isotherm chacterizing sorption as a function of solute concentration. Utilizing a constant value for K_d implies that this relationship is linear over the range of concentrations of interest. In addition, the K_d approach assumes instantaneous and reversible reactions which is often realistic in many situations. However, instances may arise where the rate of chemical reaction is slow relative to the ground water velocity leading to erroneous predictions.

More accurate and complex descriptions of the sorption/desorption processes involve determination of the thermodynamic and kinetic relationships (and controls) which exist between the various contaminants and mineralogical components. An accurate description of the sorption/desorption processes is necessary in order to effectively evaluate movement of contaminants through the ground water system.